Longitudinal study of calf morbidity and mortality and the associated risk factors on urban and peri-urban dairy farms in southern Ethiopia

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Abstract

Background

Calf morbidity and mortality are among the main causes of economic losses in dairy farms around the world. Poor calf management practices make the problem worse in developing nations like Ethiopia. This prospective longitudinal study was carried out in 70 dairy farms selected from southern Ethiopia with the aim of estimating the morbidity and mortality rates in calves and identifying the associated risk factors. To this end, a total of 274 calves were followed up every two weeks for major clinical health problems and deaths from birth to six months of age.

Results

The study revealed a morbidity rate of 12.7 cases and a mortality rate of 3.7 cases per 100 calf-months at risk in the study calves. The cumulative incidence of morbidity and mortality was also found to be 39.8% and 13.5%, respectively. Diarrhea was the leading cause of morbidity and mortality in calves, accounting for 71.3% and 62.1% of all morbidity and mortality, respectively. In a multivariable Cox regression analysis, the risk of morbidity was significantly ($p < 0.05$) lower in calves older than three months (HR = 0.22), female calves (HR = 0.57), calves raised by farmers who had completed secondary school (HR = 0.26) or college education (HR = 0.30), but it was significantly greater in calves born from dams affected with dystocia (HR = 2.4) and on farms where dairy farming is the farmers' secondary source of income (HR = 1.7). Similarly, calves aged over three months (HR = 0.14), calves separated from their dams only after ingestion of colostrum (HR = 0.40) and owned by farmers who completed secondary school (HR = 0.08) or college education (HR = 0.13) all had lower mortality rates than other groups. Calves born to cows with dystocia were 5.2 times more likely to die.

Conclusion

The study concluded that calf morbidity and mortality rates in the study area are higher than economically tolerable levels and therefore it is recommended to raise awareness among farmers to improve calf management practices.

1. Introduction

Ethiopia has the largest livestock population in Africa, with an estimated 70.3 million cattle, 9.12% of which are calves under the age of six months [1]. In Ethiopia, where calves are the future herd of a dairy farm, dairy farming is one of the most significant segments of the livestock industry. Dairy farming in urban and peri-urban regions is growing swiftly across the country as a result of rising urbanization and increased demand for milk and milk products, even though the extensive production system is still the country's leading method of livestock husbandry [2]. Urban and peri-urban dairies are semi-intensive to

intensive production systems that maintain exotic and cross-bred cows with comparatively better management practices [3]. Although the dairy industry has grown significantly in recent years, it is reportedly suffer from inefficient reproduction, a low rate of calf survival, high calf morbidity and mortality, and a high incidence of diseases such as mastitis, lameness, pneumonia, and ketosis [4].

Worldwide, dairy farmers face recurring problems with calf morbidity and mortality [5], particularly in the tropics where high temperatures and humidity promote the spread of infectious agents and make it difficult to replace heifers effectively [6]. Calf diseases result from the interplay of several factors, such as management practices in dairy farms, environmental conditions, infectious agents, and the calf itself [7]. Numerous conditions have been linked to calf morbidity and mortality; however, diarrhea in the neonatal period and pneumonia in older calves are known to be the main causes of calf hood morbidity and mortality [8]. Furthermore, several risk factors for calf morbidity and mortality have been identified, including inadequate or lack of colostral immunity, overcrowding and poor hygiene which increase the transmission of organism, overcrowding, poor hygiene, naive immune systems in newborns, stress factors such as cold ambient temperature and frequent animal mixing, calf nutrition and calf vaccination status [9].

Over the years, several studies have been conducted on calf morbidity and mortality and associated risk factors in Ethiopia. According to a systematic review and meta-analysis of calf morbidity and mortality studies in Ethiopia, the prevalence of calf mortality ranges between 0.9% and 37%, with a pooled prevalence of 14.79% [10], while the prevalence of calf morbidity falls within the range of 22.8 to 66.7% [11]. The majority of the studies, however, used a cross-sectional study methodology, which offers insufficient details regarding the scope of the issue and relevant risk factors. The other problem with previous studies in the country is the variation in the operational definition of morbidity or mortality rate and prevalence between studies. The word "rate" should only, strictly speaking, be used to describe metrics based on the idea of animal-time units. In more detail, it is a ratio where the denominator is the number of animal-time units that are at risk [12]. Furthermore, the majority of earlier studies only looked at certain known risk factors for calf morbidity and mortality. Therefore, the current study was initiated to fill these knowledge gaps and was aimed to estimate the morbidity and mortality rate in calves under six months of age and to identify the potential risk factors using a prospective longitudinal study design on dairy farms chosen from urban and peri-urban areas in southern Ethiopia.

2. Materials And Methods

2.1. Study Area

This study was carried out on dairy farms in and around the towns of Hawassa, Arsi Negelle, and Wolayta Sodo. These areas were chosen for their relatively higher potential for dairy production in southern Ethiopia. In the study area, cattle are mainly kept for milk production to be sold to the city dwellers. Hawassa, the capital of the newly established Sidama National Regional State, is located 273 kilometers south of Addis Ababa at a latitude of 7° 3' North and a longitude of 38° 28' East. The city has

an average annual rainfall of 800–1000 mm, an average temperature range of 20.1°C to 25°C, and is located at an altitude of 1708 meters above sea level. Arsi Negele is located in the West Arsi zone of the Oromia regional state, 225 kilometers south of Addis Abeba. The town lies at 7°21'N latitude and 38°42'E longitude, approximately 2043 meters above sea level. The average annual temperature ranges from 10 to 25°C, while the annual rainfall ranges between 500 and 1000 mm. Wolayta Sodo is located at 6°54'N latitude and 37°45'E longitude, and is between 1600 and 2100 meters above sea level. The average annual rainfall in the town is between 450 mm and 1446 mm, while the average annual maximum and minimum temperatures are 26.6 and 11.4°C, respectively.

2.2. Study population and management practices

According to the Livestock and Fisheries Development office of the respective municipality, there are about 107 dairy farms in Hawassa, 35 in Arsi Negele, and 33 in Wolayta Sodo. Herd sizes ranged from 2 to 131 cattle, with an average of 7 cattle per herd. The cattle husbandry system in the study farms varied from semi-intensive to intensive husbandry system. In intensive farms, the cattle were kept in stalls the whole time and fed concentrates and roughages. The cattle on semi-intensive farms grazed outside during the day and were only given supplementary feed just before milking in the morning and evening. The study population consisted of calves under six months old on all dairy farms in the towns. In this study, calves were defined as cattle less than 6 months old [13]. Although some of the calves were Jersey breeds, most were Holstein-Friesian Zebu crossbreeds. In order to breed cows, artificial insemination (AI) was used most frequently. However, if conception failed following AI or the AI technician was late, all farms used bull service as a backup.

2.3. Study design and sampling method

To achieve the aim of the study, a prospective longitudinal study was used. For this purpose, individual calves were identified and monitored regularly until the end of the study to determine the occurrence of new cases of morbidity and mortality on the dairy farms. A questionnaire survey was also conducted during the study period to collect data at herd and calf level. Farm selection was based on herd size and the farmer’s willingness to participate in the study. Consequently, 70 dairy farms with five or more cows were targeted to increase the likelihood of receiving at least one calf for follow-up. Based on these criteria, 23 farms from Hawassa, 26 from Arsi Negele and 21 from Wolayta Sodo were selected. These farms account for 40% of all farms in the areas. The total number of calves recruited for the study was 274.

2.4. Data collection

2.4.1. Questionnaire survey

A member of the dairy farm staff who was primarily in charge of managing the animals was given a semi-structured questionnaire on the initial visit to the chosen farms. The questionnaire was designed to collect data on a variety of topics that were divided into four categories: dairy farmer’s characteristics, management factors, calf factors, and dam factors. Data on the dairy farmer included the farmer's age, sex, level of education, and if dairy farming is their main or secondary source of income. The

management parameters considered were the calving facility housing arrangement, feeding arrangement, cleanliness of the calf house, umbilical health care, the time and method of colostrum feeding, weaning age, mixing of calves of various ages or calves with cows in the barns, and other factors. The calf-related data were sex, breed and age. Parity number and delivery status (normal or dystocia) were taken into account as dam factors.

2.4.2. Monitoring of calves

At each visit to the farm, new born calves were recognized individually using their ear tags, if available, or other markers employed by the investigator, and they were monitored until they were 6 months of age. Calves purchased from outside farms with known dates of birth were also included in the study. Each calf in the study was followed every two weeks until the end of the study. Every calf illness and deaths that occurred during a visit was documented using a unique data recording format that was designed for every farm. A preliminary diagnosis was obtained through clinical examination when health problems emerged. Farm attendants were asked to list and describe any health problems that occurred between visits. In addition to regular visits, emergency visits were also made in response to calls from dairy farm owners regarding calf health problems. Calves were excluded from the follow up when they are 6 months old. When the calf loss occurred during the follow-up period, the date and reason for the loss were recorded. For the purpose of this study, morbidity was defined as any illness with recognizable clinical signs or symptoms manifested by calves that ultimately results in death or justifies therapeutic intervention during follow-up, while mortality was defined as any observed death of calves over the age of 24 hours, regardless of cause.

2.5. Statistical analysis

Data acquired through questionnaire survey and prospective observation of calves were stored, filtered and coded in Microsoft Excel 2007 spreadsheets and transferred to Stata version 14.2 (Stata Corp. TX USA, 2006) for statistical analysis. The outcome or dependent variables of interest in this study were morbidity and mortality rates, which were recorded as “1” if the relevant event happened or “0” otherwise. Morbidity and mortality events were estimated as crude incidence rates. The true incidence rate is defined as the speed at which an event occurs per unit of animal-time at risk [12]. Therefore, the morbidity or mortality rate was calculated as the number of disease events or deaths that occurred during the observation period divided by the total periods at risk. The “periods at risk” which is given here as calf-months at risk represent the entire number of months that the study calves were present without experiencing any disease-related events or remaining alive during the study period. A rate was reported as per 100 calves-months at risk. Additionally, the Kaplan-Meier (K-M) life table was used to estimate the cumulative incidence of morbidity or mortality for comparison with other studies. Cumulative incidence was defined as the probability that a disease event would occur in a calf during a follow-up period (in the case of morbidity) or the probability that a calf would die (in the case of mortality). About 19 variables mentioned above in 2.4.1 were considered explanatory (independent) variables in the statistical analysis.

The Log-rank test was used to examine whether or not the categorical predictor should be included in the final model and to test the null hypothesis that there are differences between the groups of categorical predictors in the probability of an event (illness or death) at any stage. A P value cut off of 0.25 from the log-rank test was used as a standard to select a variable for the multivariable model. The risk factors associated with calf morbidity and mortality rate were examined using a multivariate Cox proportional hazards regression model. Collinearity among the predictors was checked using tabulation and correlations in which the gamma values between − 0.6 to 0.6 were used as a benchmark in each analysis [12]. The final model was built using stepwise backward elimination of non-significant variables. Potential confounders were managed at each step of model building process. A variable was deemed a confounder if coefficients of the remaining variables changed by 20%. The Schoenfeld and scaled Schoenfeld residuals were used to evaluate the assumption that the hazards in the Cox proportional hazard model are proportionate or constant across time with different predictors or covariate levels (Sullivan, 2016). $P < 0.05$ was considered significant in all analyses with a 95% confidence level.

3. Results

3.1. Description of the dairy farms

Men owned 75.7% of all farms, compared to women who owned only 24.3%. According to the level of education, 34.3%, 24.3% and 34.3% of the dairy farms were run by farmers who had completed their primary, secondary and / or college education, while 7.1% were run by farmers who had never received a formal education. For 62.86% of farmers, dairy farming was their main source of income, while for 37.1%, it was only a secondary source. On the majority of dairy farms (84.3%), the management system was intensive, with cattle housed all the time and receiving concentrates and roughages, while in the remaining 15.7%, it was semi-intensive, where the cattle grazed outside during the day and were only received supplementary feeding in the morning and evening right before milking. There were no maternity facilities on the vast majority of dairy farms (91.4%). On 77.1% of farms, newborn calves received colostrum immediately after birth, while on 22.9% of farms they received it six hours after birth. Calves were fed manually on 41.4% of farms compared to 58.6% which allowed them to take colostrum directly from their mothers. On 68.6% of the farms, calves were not kept appropriately for their ages and size, mixing is possibile, which is believed to make it easier for infectious agents to spread. In 64.3% of the farms, calves and dams are mixed together within the barns. Only 7.1% of the farms offered routine umbilical cord care to newborn calves. Unlike 20% of farms where cleaning was irregular, most farmers (80%) consistently cleaned their calf quarters.

3.2. Calf morbidity and mortality rate

Of the 274 calves monitored in this study, 101 (36.9%) had manifested one or more clinically apparent health problems, while 29 (10.6%) calves died from various causes. All follow-up calves contributed to a total of 788.45 calf months at risk. Therefore, the overall morbidity and mortality rates are 12.7 cases per 100 calf months and 3.7 cases per 100 calf months at risk, respectively (Table 1). During the follow-up

period, four calves were lost to follow up before the end of the study without showing any visible signs of morbidity.

Table 1
Morbidity and mortality rate of calves on dairy farms in southern Ethiopia based on geographical location

Geographical location	No. calves at risk	No. cases	Time at risk (months)	IR /100 calf month	95% CI for IR
Morbidity					
Arsi Negele	46	17	151.5	11.2	6.5, 17.2
Hawassa	114	37	352.95	10.5	7.6, 14.5
Wolaita Sodo	114	47	284	16.5	12.4, 22.0
Total	274	101	788.45	12.8	10.4, 15.4
Mortality					
Arsi Negele	46	9	151.5	5.9	3.6, 12.3
Hawassa	114	10	352.95	2.8	1.5, 5.3
Wolaita Sodo	114	10	284	3.5	1.9, 6.5
Total	274	29	788.45	3.7	2.7, 5.4
IR = Incidence rate					

3.3. Cumulative incidence of morbidity and mortality

In this study, in addition to the morbidity and mortality rate, we attempted to estimate the cumulative incidence of all-cause morbidity and mortality in the followed calves using the K-M life table method. The study showed that the cumulative incidence of all-cause morbidity and mortality during the follow-up period was 39.8% and 13.5%, respectively. That is, the probability of a calf remaining disease-free or alive at the end of the follow-up period was 60.2% and 86.5% on the study farms, respectively. There was a steady increase in cumulative incidence morbidity and mortality until calves reached 4 months of age and then remained the same (Table 2).

Table 2
Cumulative incidence of all-cause morbidity and mortality in calves under 6 months of age in southern Ethiopia

Age interval in months	Calves at risk	No. cases	No. censored	Cumulative incidence	95% CI
Morbidity					
0–1	274	22	8	8.52	5.74, 12.54
1–2	243	46	7	26.09	21.22, 31.83
2–3	190	14	6	31.62	26.36, 37.64
3–4	170	17	57	39.84	33.99, 46.30
4–5	96	0	74	39.84	33.99, 46.30
5–6	22	0	22	39.84	33.99, 46.30
Mortality					
0–1	274	8	23	3.05	1.54, 6.00
1–2	243	15	38	9.54	6.44, 14.02
2–3	190	4	16	11.52	8.04, 16.40
3–4	170	3	71	13.50	9.57, 18.87
4–5	96	0	74	13.50	9.57, 18.87
5–6	22	0	22	13.50	9.57, 18.87

3.4. Causes of morbidity and mortality

Diarrhea was the leading cause of morbidity and mortality accounting for 71.3% and 62.1% of the all morbidity and mortality, respectively. Pneumonia was the second most common cause of morbidity, while unknown causes are the second leading causes of death. The other common causes of morbidity and mortality are presented in Table 3.

Table 3
Major causes of morbidity and mortality in the 274 calves monitored in southern Ethiopia

Causes	Morbidity (N = 101)		Mortality (N = 29)	
	No. of cases	Percentage (%)	No. of cases	Percentage (%)
Diarrhea	72	71.3	18	62.1
Pneumonia	19	18.8	4	13.8
Septicemia	3	2.97	-	-
Joint illness	5	4.95	-	-
Navel illness	6	5.94	-	-
FMD	1	0.99	-	-
Mechanical injury	2	1.98	1	3.4
Ring worm	1	0.99	-	-
Unknown causes	-	-	6	20.7

3.5. Risk factors for calf morbidity and mortality

3.5.1. Univariate analysis

In this study, a total of 19 different host and management factors were evaluated using the Log-rank test to see their effect on calf morbidity and mortality and to select candidate predictors for the final multivariable analysis. Of these, 10 factors had p-values less than 0.25 and were selected for multivariate analysis. Similarly, of the factors analyzed with calf mortality rate, nine had p-values less than 0.25 and were selected for multivariable analysis (Table 4).

Table 4
Univariable analysis of risk factors for calf morbidity and mortality using Log-rank test

No	Variable	Morbidity		Mortality	
		χ^2	*p*	χ^2	*p*
1	Location (Arsi Negele/Hawassa/Wolaita Sodo)	2.57	0.2771	6.02	0.0493
2	Cal sex (Male/Female)	9.55	0.002	3.0	0.0834
3	Calf breed (Jersey/HF cross)	1.51	0.4697	0.13	0.9349
4	Calf age (≤ 3/>3 year)	35.92	0.0000	10.18	0.0014
5	Calving difficulty (Yes/No)	9.28	0.0023	23.04	0.000
6	Dam's parity (Primiparous/Multiparous)	0.09	0.7702	3.01	0.0825
7	Management system (Intensive/Semi-intensive)	0.00	0.9829	0.10	0.7507
8	Farmer's education (No formal edu/primary/secondary or college edu)	10.53	0.0145	14.03	0.0025
9	Herd size (≤ 10/>10)	0.02	0.8996	0.02	0.8907
10	Calving facility (Yes/No)	5.84	0.0156	0.09	0.7621
11	Calf housing (Individual/Group)	1.29	0.2561	0.61	0.4333
12	First time calves ingested colostrum (≤ 6 hrs/>6 hrs)	2.04	0.1530	0.02	0.8775
13	Time calves are separated from dams (Immediately/after sucking colostrum)	0.08	0.7726	7.76	0.0053
14	Method of colostrum administration (Sucking/Hand-fed)	1.12	0.2892	1.86	0.1727
15	Umbilical care (Yes/No)	5.04	0.048	0.06	0.8125
16	Mixing of calves of different ages (Yes/No)	2.94	0.086	0.14	0.7082
17	Mixing of calves and cows in the barn (Yes/No)	0.04	0.8441	1.25	0.2639
18	Hygiene (Good/Poor)	4.2	0.1225	3.18	0.2038
19	Dairying as a primary income source (Yes/No)	8.26	0.004	1.85	0.1735

3.5.2. Multivariable analysis

Calf morbidity rate: In the final multivariable Cox regression analysis model, it was found that calf age, calf sex, calving difficulty, whether dairy farming is a primary or secondary source of income, and the educational status of the farmer have a significant ($p < 0.05$) impact on the incidence rate of calf morbidity. Accordingly, the risk of morbidity was lower in calves over 3 months (HR = 0.22), female calves

(HR = 0.57), and in farms owned or managed by farmers who completed secondary education (HR = 0.26) or college education (HR = 0.30) compared to their peers. The risk of morbidity was higher in calves of cows with dystocia (HR = 2.4) and from dairy farms owned by farmers whose primary source of income is not dairy farming (HR = 1.7) (Table 5). The final model was tested for the proportional hazards assumption and found not to violate the assumption (global test: ^{2} = 6.08; df = 5; p = 0.2985).

Table 5
Risk factors for calf morbidity rate based on multivariable Cox regression analysis

Variables	Category	HR	Std. Err	z	P > z	95% CI for HR
Calf age	≤ 3 mon	Ref				
	> 3 mon	0.22	0.06	-5.23	< 0.001	0.12–0.39
Calf sex	Male	Ref				
	Female	0.57	0.14	-2.37	0.018	0.36–0.91
Calving difficulty	No	Ref				
	Yes	2.4	0.91	2.29	0.022	1.13–5.03
Dairy farming as a primary source of income	Yes	Ref				
	No	1.7	0.39	2.18	0.029	1.05–2.65
Farmer's education	No formal edu	Ref				
	Primary	0.61	0.23	-1.33	0.184	0.30–1.26
	Secondary	0.26	0.13	-2.70	0.007	0.10–0.69
	College	0.30	0.10	-3.61	< 0.001	0.16–0.58

HR: hazard ratio

Calf mortality rate: The final multivariate Cox hazard regression analysis model showed that of the potential risk factors assessed, calf age, calving difficulty, time of separation of calves from the dams, and the educational status of the dairy farmers had a significant ($p < 0.05$) effect ($p < 0.05$) on the calf mortality rate on dairy farms in southern Ethiopia. The mortality risk was lower in calves over 3 months (HR = 0.14), in calves separated from dams only after sucking colostrum (HR = 0.40), and in calves from farms owned or managed by farmers who had completed primary school (HR = 0.28), secondary

education (HR = 0.08) or tertiary education (HR = 0.13) compared to their peers. The risk of mortality was higher in calves from cows with dystocia (HR = 9.3) (Table 6). The final model was tested for the proportional hazards assumption and found not to violate the assumption (global test: ^{2} = 4.82; df = 4; *p* = 0.1853).

Table 6
Risk factors for calf mortality rate based on multivariable Cox regression analysis

Variables	Category	HR	Std. Err	z	P > z	95% CI for HR
Age of calves	≤ 3 mon	Ref				
	> 3 mon	0.14	0.09	-3.12	0.002	0.04–0.48
Calving difficulty	No	Ref				
	Yes	9.3	5.2	3.96	< 0.001	3.08–28.02
Time of separation of calves from dams	Immediately after birth	Ref				
	After sucking colostrum	0.40	0.17	-2.20	0.028	0.18–0.90
Farmer's education	No formal edu	Ref				
	Primary	0.28	0.19	-1.87	0.061	0.07–1.06
	Secondary	0.08	0.08	-2.35	0.019	0.01–0.65
	College	0.13	0.08	-3.45	0.001	0.04–0.41
HR: hazard ratio.						

4. Discussion

The present study has shown that the crude morbidity and mortality rate of calves in the study areas is 12.7 cases per 100 calf months and 3.7 cases per 100 calf months at risk, respectively. In addition, the present study revealed that the cumulative all-cause morbidity and mortality in the examined calves was 39.8% and 13.5%, respectively. There are methodological differences in the calculation of the morbidity or mortality rate in previous studies in Ethiopia, with the exception of one study [14]. The current morbidity and mortality rate is comparable to the crude morbidity and mortality rate reported by Hordofa et al. [14], which was 13.81 cases/100 calf months and 4.12 cases / 100 calf months, respectively. The cumulative incidence of morbidity in the current study is substantially lower than the 50.12 to 66.7% range of values that have been reported from different parts of the country [14–17]. But, it exceeds the cumulative

incidence of 29.3–34.1% found in other studies [18, 11]. Additionally, the cumulative mortality incidence found in the present study is lower than the incidence ranges reported in earlier studies (20.04–30.7%) [14–17, 19] although higher than the figures, 9.3% and 8.64%, reported by Megersa et al. [18] and Tora et al. [11], respectively. The current cumulative incidence of mortality is higher than estimates from Europe, which vary from 1 to 9% [8, 20, 21], although it is within the range (13.0–30.0%) estimated from other African countries [22]. Agroecology, case definition, age of the calves, study methodology, sample size, and a number of calf- and herd-level risk factors can all be used to explain variations in morbidity and mortality rates among studies [23].

The current study on calf morbidity and mortality evaluated a wide range of potential risk variables. Accordingly, multivariate Cox regression analysis found that calf age, calf sex, calving difficulties, whether dairy farming is a primary or secondary source of income, and dairy farmers' educational status were risk factors for calf morbidity, while calf age, calving difficulties, the time when calves were separated from their dams, and educational status were risk factors for calf mortality.

In the present study area, the risk of morbidity and mortality in calves over 3 months of age was 78% (HR = 0.22) and 86% (HR = 0.14) lower, respectively, than in calves under or equal to 3 months of age. In keeping with our findings, research from Ethiopia and elsewhere have also demonstrated that calf morbidity and mortality rates are significantly greater in the early life of calves particularly during the first month of a calf's life [5, 8, 15, 16, 20]. In general, the relatively higher risk of morbidity and mortality in young calves found in previous and current studies implies that dairy producers need to give due attention and provide the best possible health care for calves at early age of life.

The risk of morbidity was 43% (HR = 0.57) lower in female calves than in male calves, according to the current study. The mortality rate was similarly higher in male calves than in female calves although the difference was not statistically significant. This is probably related to the better management and health care services provided for female calves in the farms because female calves are considered future replacement stocks on farms and are of greater economic significance. When it comes to feed, medical treatment, and other things, male calves frequently receive less attention. Other studies conducted in Ethiopia and abroad have also found that male calves have higher morbidity and mortality rates than female calves [18, 24, 25].

When comparing calves born from dams with and without calving difficulties, calves born from dams affected with dystocia had a 2.4 and 9.3 times higher risk of morbidity and mortality, respectively. This outcome is consistent with earlier studies [14, 20, 26, 27]. Due to the high possibility of contamination during delivery and delayed suckling or decreased colostrum intake, assisted delivery increases the risk of disease and mortality [28]. Furthermore, due to stress during delivery, adrenocorticotropic hormone is released. This hormone stimulates the adrenal cortex to produce and secrete more cortisol, leading to immunosuppression and increasing calves' vulnerability to numerous pathogens [29].

Dairy farming was the principal business for 62.86% of the owners in the current research area, although it was only the 37.1% owners' secondary source of revenue. The risk of morbidity was 1.7 times higher on

dairy farms where dairy farming is the farmer's secondary source of income. This is related to the fact that farmers devote less time to caring for calves since they spend a great deal of their time engaged in other activities that would give them a better income.

While some dairy farms in the current research locations leave the newborn with their mothers for a few hours so they can suck as much colostrum as they can, some dairy farms withdraw calves from their dams soon after birth and offer colostrum after six hours. The mortality risk was found to be 60% (HR = 0.40) lower in calves who were allowed to stay with their mothers and consume colostrum immediately than in calves that were taken away from their mothers right away and fed colostrum by bottle after some delay. The most likely explanation for this is that the calves that were left with their dams after delivery were able to consume enough colostrum to give them adequate protection from infectious pathogens. Contrarily, calves that are taken away from their mothers and bottle-fed may not receive enough colostrum at the right time. In light of this, it is advised that the health and survival of calves depend on the consumption and absorbing adequate colostrum (10–12% of their body weight) within 24 hours after birth [30].

The farmers' level of education had a significant ($p < 0.05$) effect on the morbidity and mortality rates of calves in the present study. Compared to farms owned by farmers without formal education, it was found that the risk of morbidity was reduced by 74% (HR = 0.26) and 70% (HR = 0.30), respectively, in farms owned by farmers who finished secondary and college education. Similarly, there was a 92% (HR = 0.08) and 87% (HR = 0.13) reduction in mortality risk on the farms of farmers who completed secondary and college education, respectively. This shows that farmers with higher educational levels had a better understanding of the care and other management techniques for calves that led to a low risk of morbidity and mortality.

In the present study, diarrhea was the most frequently observed disease syndrome and the leading cause of calf mortality followed by pneumonia. Diarrhea accounted for 71.3% of overall morbidities and 62.1% of all mortalities. Similar to the current data, other authors in Ethiopia have identified that diarrhea and pneumonia are the two most significant health issues affecting calves [11, 14–17, 31]. In studies conducted outside Ethiopia, the two disease conditions were likewise included as the primary and secondary causes of calf morbidity and mortality [32, 33]. The incidence of diarrhea was more noticeable in calves that were very young, and this may be because newborn calves are more sensitive to agents that cause diarrhea in addition to not receiving enough colostrum in a timely manner, which results in inadequate passive immunity [34]. Poor hygiene management of feeding utensils, the calving environment, and the calf pen may also be contributing factors to the occurrence of diarrhea as a cause of calf morbidity and mortality. Worldwide, diarrhea is a major cause of economic loss to cattle producers through high morbidity and mortality in calves, especially in the first few weeks of life. Therefore, it is crucial to determine the root causes of diarrhoea to manage it and its effect on the growth of the calf growth and future output. Therefore, understanding the underlying causes of diarrhoea should be taken into account in future calf morbidity and mortality studies in the country. Additionally, the present study found that 20.7% of calves died from unexplained causes. Therefore, future studies will need to employ

highly sensitive diagnostic methods to help identify the primary infectious and noninfectious causes of calf death in the dairy farms under observation and elsewhere.

Conclusions

The present study has revealed higher morbidity and mortality rates of calves on dairy farms in southern Ethiopia. The reported morbidity and mortality rates are higher than what can be attained by sound management and is therefore not economically justifiable. This indicates short-term and long-term negative impacts on dairy production and replacement stocks. The study also found that diarrhea, pneumonia, and other undiagnosed diseases are the most common causes of calf morbidity and mortality in the study area. Male calves, calves under three months old, calves from dystocia-affected dams, calves from farms where dairy farming is the farmer's secondary source of income, and calves from farms run by farmers without a formal education all had a considerably increased risk of morbidity. Similar to this, calves under 3 months of age, those born to dams affected by dystocia, those taken away from their mothers soon after delivery, and those raised on farms run by farmers without formal education had a considerably increased risk of dying. Therefore, it is crucial to educate dairy farmers about good calf management practices, notably timely provision of sufficient colostrum and the proper management of dystocia cases as well as calves born with dystocia, in order to lower calf morbidity and mortality rates and, ultimately, improve the profitability of dairy production in the study area.

Declarations

Ethics approval and consent to participate

This research was approved by the Institutional Research Ethics Review Committee of Hawassa University. All methods are carried out in accordance with the ARRIVE guidelines. Before conducting the study, the objectives, expected results, and benefits of the study were explained to the dairy farm owners or managers who participated in the study and written informed consent was obtained from all dairy farms.

Consent for publication

Not applicable

Availability of data and materials

All data generated or analyzed during this study are included in this article and are available from the corresponding author upon reasonable request.

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Competing interest

The authors report that there is no conflict of interest to declare.

Authors' contribution

RA designed the study, analyzed and interpreted the data, and was a major contributor in writing the manuscript. YL, TM and WT participated in data collection and draft manuscript writing. AR, AF and DS participated in data analysis and critically reviewed the manuscript. All authors read and approved the final manuscript.

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