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Interventions to reduce camel and small ruminant young stock morbidity and mortality in Ethiopia

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ABSTRACT

Morbidity and mortality of young stock is a challenge for livestock producers globally. In Ethiopia, where camels and small ruminants (sheep and goats) are essential smallholder and pastoral livestock, young stock losses can cause severe consequences to livelihoods.

This pilot study, part of a Government-led Young Stock Mortality Reduction Consortium project, was undertaken to identify and evaluate interventions to reduce young stock mortality in mixed crop-livestock and pastoral production systems in Ethiopia. Pastoralists and mixed crop-livestock farmers were enrolled by convenience sampling across four regions. Households were sampled with questionnaire surveys to establish baseline mortality risk and prevalence of diarrhoea and respiratory disease in animals younger than one year, and followed longitudinally over a one-year period, with final evaluations conducted from March to July 2020. Mortality risk and prevalence of diarrhoea and respiratory disease before and after implementation were compared using Poisson regression models including household as random effect.

Prior to intervention, median camel mortality, prevalence of diarrhoea, and respiratory disease across production systems in the different households was 0.4, 0.44 and 0.2, respectively. This compared to median pastoralist small ruminant mortality risk and prevalence of diarrhoea and respiratory disease of 0.45, 0.32 and 0.18, respectively. Post-intervention, median camel mortality, prevalence of diarrhoea and respiratory disease dropped to 0.1, 0.08 and 0. Similarly, more than half of the small ruminant households reported no mortality, and no cases of diarrhoea or respiratory disease. In camels, rate ratios of mortality risk, prevalence of diarrhoea, and respiratory disease post-intervention compared to the baseline were 0.41, 0.41 and 0.37. In small ruminants, rate ratios were 0.33, 0.35 and 0.46. All reductions were statistically significant ($p < 0.01$). Generally, pastoralists experienced higher mortality and disease prevalence compared to mixed crop-livestock smallholders, and the effect of intervention was slightly higher in pastoralist households.

The pilot study findings demonstrated highly significant reductions in mortality and risk of diarrhoea and respiratory disease post-interventions. However, not all households benefitted from the interventions, with a few households reporting increased mortality and morbidity. Many households had very few animals which made it challenging to measure impact and the study was conducted over a single year, without a control group, so

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between year effects could not be accounted for in the reductions observed. These findings should contribute to improved livestock productivity in Ethiopia.

1. Introduction

Morbidity and mortality risks in camel and small ruminant young stock are a challenge for livestock producers globally. In Ethiopia, where camels and small ruminants (sheep and goats) are essential smallholder and pastoral livestock, young stock losses can cause severe consequences to livelihoods. Pastoralist and mixed crop-livestock systems comprise the majority of farms in Ethiopia (Management Entity, 2021), where pastoralists own the majority of camels which they keep as a source of milk, meat and hides, and as a financial investment (Dawo, 2010). Together with smallholders, they also own most of the nation's small ruminants, raised predominantly for milk, meat, wool, manure, cash sources, and risk distribution (Tibbo et al., 2006). In 2020, pastoralists, smallholders and other livestock owners held a total of 8 million camels, 43 million sheep, and 53 million goats (Central Statistical Agency of Ethiopia, 2021), making Ethiopia's livestock population the largest in Africa. Keeping livestock healthy and productive is a challenge for both pastoralists and smallholders (Fentie et al., 2016; Mayberry et al., 2018), with national estimates of mortality for 2020 fiscal year (excluding nomadic areas) of 0.53 million (6.6 %) camels, 6.51 million (15.1 %) sheep, and 8.74 million (16.5 %) goats (Central Statistical Agency of Ethiopia, 2021).

Mortality and morbidity rates are high in Ethiopia, especially in young stock (Shapiro et al., 2015), yet studies are scarce. In the limited number of recent studies of young stock mortality, mortality rates of 14.9–35.6 % have been reported in camel calves (Awoke and Ali, 2015; Megersa et al., 2008). Mean mortality rates of 14.9–33.5 % in lambs (Fentie et al., 2016; Hadgu et al., 2021) and 17.6–50 % in kids have been reported (Debele et al., 2013; Dereje et al., 2015; Fentie et al., 2016; Mayberry et al., 2018). Tifashe et al. (2017) observed sheep and goat mortality rates of 7.04 % and 10.4 %, respectively, with highest rates in lambs (9.6 %) and kids (12.3 %), followed by young stock (6 % sheep; 14.3 % goats) and adults (4.7 % sheep; 8.75 % goats). Camel mortalities are predominantly due to infectious diseases (Khalafalla and Hussein, 2021) and respiratory problems (Fentie et al., 2016; Megersa, 2014; Zeleke, Bekele, 2000), with more than 60 % of deaths in camel calves less than three months of age (Megersa, 2014). Fentie et al. (2016) found the most common cause of mortality in both lambs and kids was disease and Debele et al. (2013) found diarrhoea to be the major cause of mortality (83.3 %). Where reported, diarrhoea has been described as the predominant cause of morbidity in camel calves (Abraha et al., 2019; Ahmed and Hedge, 2007; Gebru et al., 2018). Morbidity has been observed as 16–27.3 % in lambs (Hadgu et al., 2021; Tifashe et al., 2017) and 10 % in kids (Tifashe et al., 2017). The most common cause of morbidity was respiratory disease in lambs (9.6 %) and gastrointestinal disease in kids (Tifashe et al., 2017).

Management practices are thought to contribute to camel mortality (Awoke et al., 2015; Megersa, 2014) and have previously been shown to be the predominant cause of sheep and goat mortality (Bekele et al., 1992; Hadgu et al., 2021; Njau et al., 1988; Tifashe et al., 2017; Wilson et al., 1985). Good management practices such as supplementary feeding, good hygiene and proper housing have been shown to reduce young stock losses (Genfors et al., 2023; Holmøy et al., 2012). It is important to understand morbidity and mortality risks to identify management problems, to guide research and to understand how they affect livestock development objectives and inform policy making processes to implement priority investment interventions and increase productivity (Shapiro et al., 2015). To contribute to understanding and addressing young stock morbidity and mortality in Ethiopia, in 2016 the Young Stock Mortality Reduction Consortium (YSMRC) was formed under the auspices of the Ethiopian Ministry of Agriculture (MoA), aligned with national objectives in the Ethiopian Livestock Master Plan (LMP) (Shapiro et al., 2015), as a highly collaborative effort (see Wong et al., 2022 for more detail about the consortium). The LMP objectives for livestock included poverty reduction, improved food security, national income growth and climate mitigation and adaptation. The Livestock Sector Analysis of the LMP indicated that improvements in health of sheep, goats and camels could be achieved when combined with better management and health interventions, to reduce young stock mortality and improve productivity (Shapiro et al., 2015). Management practices and interventions listed included vaccinations, parasite control, improving grazing, provision of health services and feeding practices. Together with the Ethiopian MoA, the YSMRC represented an innovative collaboration with a tripartite funding mechanism.

The YSMRC set out to design, implement and monitor interventions targeted for small scale livestock producers in the major production systems of Ethiopia. This pilot study describes mortality and morbidity risks in camel and small ruminant young stock and a series of interventions implemented to reduce young stock losses.

2. Materials and methods

2.1. Ethical approval

Ethical approval was obtained from the Institutional Animal Care and Use committee at the University of California, Davis (Protocols #19666 & #21995), and also from the Institutional Review Board of AAU-ALIPB for animal and human participants, and the farmer questionnaire survey (ALIPB/IRB/016/16/17). A privacy policy statement was explained by the enumerators to the farmers before answering the questionnaires, and the enumerators had to confirm (by ticking a box in the survey) that the farmers understood and agreed with the privacy policy, and agreed to take part in the survey. Informed consent was obtained from all subjects involved in the study.

2.2. Study area and household selection

Study regions representing pastoral and mixed crop-livestock systems in Ethiopia were selected in consultation with livestock health extension officers from the MoA, with selection criteria including livestock population density and accessibility. Four study districts were selected across four regions of Ethiopia (Fig. 1 and Table 1). Camels were enrolled in pastoralist systems only, and small ruminants were enrolled in both pastoralist and mixed crop-livestock systems.

Within each of the four study districts, three kebeles were selected per district (kebeles generally have three villages, each with 150 households). Within each kebele, one village was purposively selected, with 50 households from that village then randomly selected, resulting in 150 households per district. To avoid substantial differences in traditional practices during the implementation phase, neighbouring kebeles within a district were selected. In total, 600 households were invited to enroll in the study, representing 12 villages from 12 kebeles, in four districts.

Households were identified from regional livestock office registers and households were eligible if they owned at least one of the following: pregnant camels, or camels with camel-calf of < 6 months of age; pregnant sheep or goats, or sheep or goats with lambs or kids of < 6 months of age. Sheep and goats were aggregated in the study and are referred to as small ruminants herein. Households were followed longitudinally over one year. Households were excluded from the study population where no animals were born in the past 12 months, either at baseline or final evaluations, or where information on mortality or disease was not available at both baseline and final evaluation. Only households present for both the baseline and final evaluations, with sufficient data to calculate mortality, were included in the subsequent summaries and analyses. It is important to note that the intervention packages were a pilot study, implemented by the government, to assess applicability for scaling up.

2.3. Study design

The experimental pre/post research study, designed to compare before and after planned interventions, without the use of a control group, aimed to evaluate intervention strategies to reduce young stock morbidity and mortality in livestock production systems in Ethiopia. The interventions were developed to align with national objectives detailed in the Ethiopian LMP i.e. they were designed to be appropriate and sustainable for the locale. The study expanded on previous health intervention packages developed by the MoA and Tufts University, as findings from previous assessment of young stock mortality causes (Fentie et al., 2016).

Staggered baseline evaluations were conducted across different study sites between March and August 2019, prior to the introduction of the interventions. Standard operating procedures (SOPs) to guide the interventions were collaboratively developed and refined (from 2017 to 2018). Year-long interventions were implemented following the baseline data collection, and the staggered final evaluations ran between March and July 2020, timed to match the baseline evaluation as best as possible to limit seasonal variations. Questionnaires and all SOPs developed for the interventions are available in Supplementary Material. Epidemiological field work and interventions for calves were conducted in parallel, and have been reported previously (Wong et al., 2022).

2.4. Interventions

Questionnaires and SOPs were developed to guide the interventions. The SOPs were translated into the three most spoken languages, Amharic, Oromifa and Somali. Originally highly detailed and with many components, the intervention packages were focused down to key interventions, selected for impact and reproducibility potential. The project was designed to be sustainable beyond its completion, and to support existing veterinary vendors, or new vendors where there were none, to provide supplies. Supplies were generally provided to households by the project, and where there were limited supplies provided, farmers/pastoralists purchased them, which was within their capacity to do so.

Training of trainers (extension officers) was carried out at Addis Ababa University College of Veterinary Medicine and Agriculture before extension officers provided training to participants at village level. Participants were trained to carry out interventions and supported by extension officers who worked closely with the participants over the year. A monitoring and evaluation plan was developed, with a results framework, through which indicators were selected to monitor intervention uptake and change. Monitoring was carried out by the same extension agents who trained the participants, with one extension agent assigned to 50 households, visiting each household every ten days to ensure training was being followed and reporting to project leads. Farmer/pastoralist training for a total of 22 interventions was provided but it was not practical to monitor all interventions. A subset of eight camel interventions were selected for monitoring purposes (Table 2). Due to logistical limitations it was not possible to monitor which of the interventions presented to the small ruminant farmers had been implemented after the farm visit.

For camel interventions, changes in practice between baseline and final evaluation were assessed, where households were evaluated as having 1) made an improvement to practices; 2) made no change but were already practicing the recommended practice; or 3) made no change and were not practicing the intervention as recommended or had a negative change.

2.5. Data collection

Data were collected at baseline and final evaluations, and included reproductive parameters (e.g. birth and death of young stock), health outcomes (e.g. incidence of diarrhoea and respiratory disease) and intervention uptake. Baseline and final mortality, diarrhoea and respiratory disease risk were calculated for camel calves and small ruminants, as well as risk of death from malnutrition for camel calves. For small ruminants, a limited amount of data was collected from enrolled households. For both pastoralist and mixed crop-livestock households, data on the number of small ruminants born (dead or alive) was collected. However, data on the number of stillbirths was collected for mixed crop-livestock households, while data on small ruminants that died in the first week of age was collected in pastoralist households. Therefore, rather than calculating risk parameters for total number of small ruminants born alive, it was only possible to use this for mixed

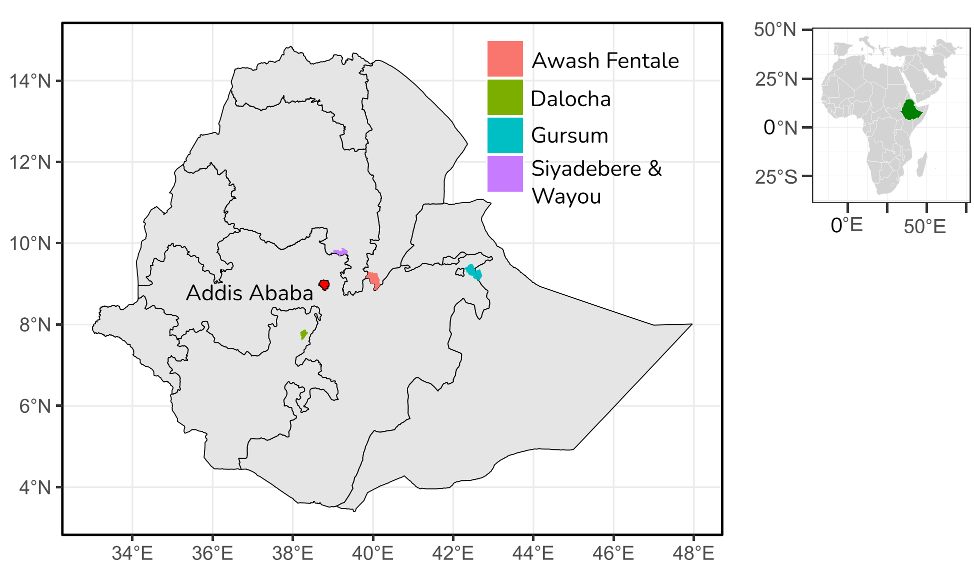

Fig. 1. Map of Ethiopia showing study sites. Data from GADM, https://gadm.org.

Table 1
Study regions, districts, production systems, and household counts pre- and post-intervention.

Species	Region	District	Production System	No. of households	Pre-intervention				Post-intervention			
					Median household size (adult females)	Median no. of calvings	Total no. adult females	Total no. calvings	Median household size (adult females)	Median no. of calvings	Total no. adult females	Total no. calvings
Camels	Afar	Awash Fentale	Pastoralist	100	13	5	1,364	529	16	5	1,622	591
	Somali	Gursum	Pastoralist	13	8	4	130	66	6	4	88	55
Small ruminants	Afar	Awash Fentale	Pastoralist	131	45	17	6,166	2,861	54	21	7,692	3,451
	Somali	Gursum	Pastoralist	80	8	6	953	611	7	4	758	410
	Amhara	Siyadebere & Wayou	Mixed crop-livestock	109	5	3	620	402	5	3	603	350
	SNNPR	Dalocha	Mixed crop-livestock	83	3	2	275	169	2	2	238	202

SNNPR = Southern Nations, Nationalities, and Peoples' Region

crop-livestock households, while total number of small ruminants still alive after the first week was used for pastoralist households.

We defined young stock mortality as the number of animals that were reported to have been born alive but died during the 12 months before and 12 months after training the participants on the interventions. Because of variations in the survey, for small ruminants in pastoralist households, stillbirths and mortality in the first week of life were reported together, so only mortality after the first week of age was included in the calculation of young stock mortality. We defined young stock diarrhoea and respiratory disease as number of animals under the age of six months that were reported in the survey to have shown signs of disease. For camels only, we defined young stock mortality due to malnutrition as the number of camels that were reported to have died due to malnutrition during the 12 months before and 12 months after the intervention. Causes of camel and small ruminant morbidity and mortality were not confirmed by veterinarians or animal health workers.

The outcome was the total number of events, not the proportion of death or disease in the household. This was done primarily because of the large proportion of households in the study population that only had very few parturitions during the study period, with a single death relating to up to 100 % mortality. We were also interested in calculating the economic benefits of the intervention to a household, which is based on the number of additional animals that survive into their productive years. Additionally, failure to accurately recollect the number of parturitions over the previous year could lead to biased estimates. For completion, we also report the number of events per 100 parturitions in a household in the year before and after the intervention.

2.6. *Data analysis*

The number of animals that were diseased or died in a household over a period of one year before and after the interventions were summarized in box and whisker plots. Data were analysed using Generalized Linear Mixed-Effects Models in R (package lme4), where the number of events was treated as a poisson distributed variable and household was included as a random effect. All interactions were tested using Likelihood ratio tests. For the analysis of the number of events in camels (deaths, diarrhoea, respiratory disease and malnutrition-related deaths) we controlled for the effect of district and tested for an interaction of district*intervention. The interaction term was not significant and dropped from the final model. For the analysis of the number of events in small ruminants (deaths, diarrhoea and respiratory disease) we additionally controlled for the effect of system (pastoralist or smallholder) and tested for an interaction of system*intervention. Due to restriction of sample size, the full model did not converge, so the effect of district was dropped from the final model. The random herd effect absorbs variations due to herd size; herd size was therefore not included in the analysis as fixed effect or offset variable.

3. Results

At the study baseline, a total of 160 households were enrolled in the camel study, and 543 households in the small ruminant study. Some households were enrolled in more than one study if they raised more than one livestock species. For small ruminants, a higher percentage of pastoralist households were lost to follow up than from mixed crop-livestock systems (Table 3).

3.1. *Camels*

At the study baseline, a total of 160 pastoral households were enrolled in the study, with 31 in Gursum and 129 households enrolled in Awash Fentale; at final evaluation there were 20 households in Gursum and 115 in Awash Fentale. After excluding those households with no animals born in the past 12 months, there were 13 households in Gursum and 100 in Awash Fentale, giving a total of 113 households included

Table 2
Name and description of camel interventions for which household-level data were collected at baseline and final evaluations.

Intervention	Description of recommended practice	Question	Response levels (in order of optimal to least optimal level)
Calf supplementary feed	Introduce good quality hay and protein supplement.	Do you provide supplementary feed (other than milk or milk replacement) to non-weaned camel calves?	Almost always Sometimes Never
Examination of sick calves	Seek help from animal health professionals when calves are sick, to enable appropriate treatment and sample collection.	Are sick camel calves examined for a disease by a health personnel?	Almost always Sometimes Never
Age calf supplementary feed introduced	(Not specified)	When do you introduce feed different from milk/milk replacer to camel calves?	< 1 month 1–2 months > 2 months I don't use supplementary feed
Frequency of water provision	Provide adequate water for lactating camels ever day/every other day and camel calves as required.	How often do you provide water to non-weaned camel calves?	Twice per day Once per day Every other day Do not provide water
Colostrum	Ensure newborn suckles dam within first six hours of birth and maintain free suckling for at least four days.	Did the camel calves born during the last 12 months get colostrum in the first day of life?	All of them Most did Many didn't
Amount of milk fed	Ensure dam is producing sufficient milk and leave at least two quarters for calf up to six months of age; otherwise foster feed or utilise nipple feeders/bucket feeding.	What is the amount of milk fed daily to newborn camels?	Leave one quarter Leave half quarter Residual suckling
Separate pregnant camels	Retain dams around the homestead one week before to one week after parturition, providing a separate, clean, dry enclosure.	Do you keep pregnant camels separated when approaching parturition?	Almost always Sometimes Never
Supplement pregnant camels	Feed browse legumes or locally available feeds like acacia pods, groundnut pods, oil seed cake, sorghum, maize, green and dry fodder supplements with plenty of water. Feed quantity should be increased by 25 % to support the requirements of the growing fetus OR Gradually introduce 4 kg groundnut cake/other oil seed by-products or other available concentrate feeds per head daily and allow for preferential browsing (shrub, acacia, cactus) to improve milk yield.	Do you provide supplements to pregnant camels when approaching parturition?	Almost always Sometimes Never

Table 3
Number of enrolled households across species, production system and district at baseline, final, and number of households included in data analyses.

System	District	Camels			Small ruminants		
		Baseline	Final	Households with animals born in past 12 months^	Baseline	Final	Households with animals born in past 12 months^
Pastoralist	Gursum	31	20	13	117	91	80
	Awash Fentale	129	115	100	146	144	131
	Total	**160**	**135**	**113**	**263**	**235**	**211**
Mixed-crop *	Siyadebere & Wayou				147	135	109
	Dalocha				133	127	83
	Total				**280**	**262**	**192**
Total		**160**	**135**	**113**	**543**	**497**	**403**

* Camels enrolled in pastoralist systems only. ^ Final households included in the study (after excluding households with no animals born in past 12 months.

in the subsequent descriptive statistical summaries and analysis.

3.1.1. Mortality, diarrhoea, respiratory disease and malnutrition in camel calves

Pre-intervention, more than three quarters of pastoralists in Awash Fentale reported at least one death, ranging from zero to nine deaths per household. More than three quarters had at least one calf with diarrhoea, more than half had at least one calf with respiratory disease, and more than half had at least one camel calf that died from malnutrition (Fig. 2A). Compared to pastoralists in Awash Fentale, households in Gursum reported lower number of deaths and disease in camel calves, with at least half of the households reporting no diarrhoea, no respiratory disease and no death due to malnutrition (Fig. 2A). For households in both districts together, the median number of deaths, diarrhoea, respiratory disease and death from malnutrition was 0.4, 0.44, 0.2 and 0.2, respectively.

Post-intervention, several pastoralists from both study districts reported fewer deaths and disease (Fig. 2A). The average household experienced a reduction of one fewer camel calves dying, ranging from up to 10 fewer deaths to six additional camel calves dying after the intervention. A quarter of all households either had no change in mortality or at least one additional death post-intervention (Fig. 2B). For households in both districts together, the median number of deaths, diarrhoea, respiratory disease and deaths from malnutrition was 0.1, 0.08, 0 and 0, respectively.

Comparing the number of events pre- and post-intervention, the poisson model showed that pre-intervention, pastoralists had a 2.08 times higher rate of camel calf deaths, a 2.16 times higher rate of diarrhoea, a 2.42 times higher rate of respiratory disease, and a 15.23 times higher rate of death due to malnutrition (Supplementary material). In all models, the effect of intervention was statistically significant ($p < 0.05$); the effect of the intervention was not significantly different in the two districts (p-value of the likelihood ratio test comparing the poisson model with interaction (district*intervention) to the model without the interaction term was > 0.05 for all outcomes).

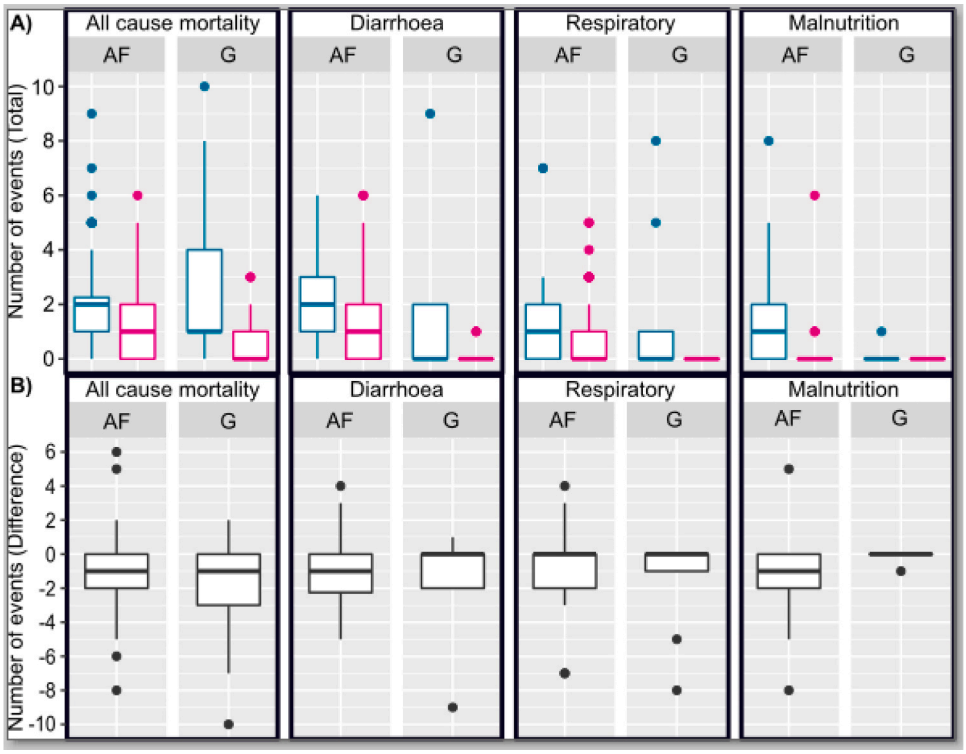

Fig. 2. a) Box and whisker plots showing number of deaths and cases of diarrhoea, respiratory disease and death from malnutrition in camel calves, in each pastoral area. Baseline measures are represented in blue and post-intervention represented in red. b) Box and whisker plots showing change in mortality and cases of diarrhoea, respiratory disease and death from malnutrition in camel calves, in each pastoral area. AF = Awash Fentale; G = Gursum.

3.1.2. Camel intervention uptake

Households were counted as performing an intervention if the response was anything greater than the minimum level. At baseline, households were practicing an average of 5.1 interventions (standard deviation 1.5) in the previous 12 months. At final evaluation, households were practicing an average of 7.7 interventions (standard deviation 0.5).

Six of the eight monitored interventions had a high level of uptake (>

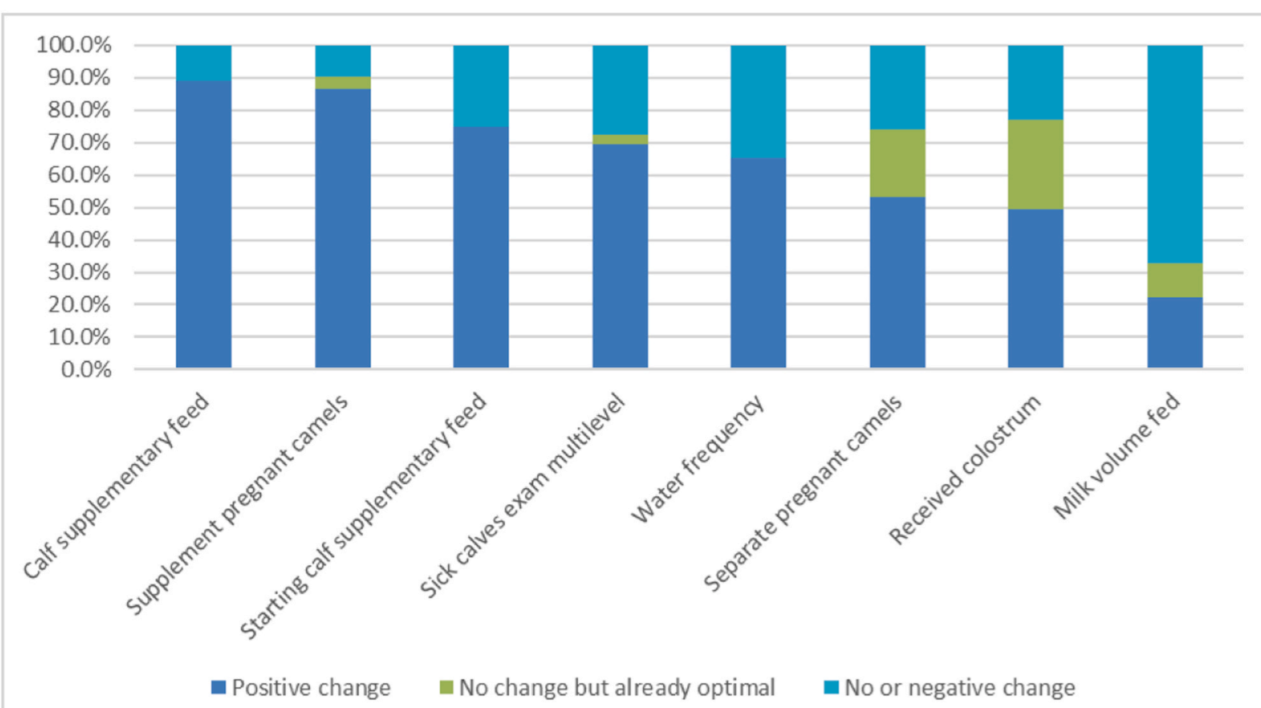

Fig. 3. The proportion of all enrolled households with baseline and final evaluation data with either a) positive change within intervention areas, b) no change in intervention area practices during the study period, but were already optimal at the start of the study, or c) no or negative change in the intervention area.

50 % of households) (Fig. 3), with the largest improvements seen in the use of calf supplementary feed (89 % households improved their practices), and supplementary feeding of pregnant camels (87 % improved). The practice of giving colostrum had the highest proportion (27 %) of households with no change due to optimal practice, with 50 % of households improving the practice. For two of the interventions, a relatively larger proportion of households reported either no change or a negative change in practice – these were the frequency of water provision (35 % households reporting no or negative change) and the volume of milk fed (67 % of households).

3.2. *Small ruminants*

At the study baseline, a total of 263 pastoral and 280 mixed crop-livestock households were enrolled in the study. After excluding those households with no animals born in the past 12 months, there were 80 pastoral households in Gursum and 131 in Awash Fentale; and 109 mixed-crop livestock households in Siyadebere & Wayou, and 83 in Dalocha. This resulted in a total of 211 pastoral households and 192 mixed crop-livestock households included in the subsequent descriptive statistical summaries and analysis.

3.2.1. *Mortality, diarrhoea and respiratory disease risk in small ruminants*

Pre-intervention, more than three quarters of pastoralists in Awash Fentale had a least five deaths, ranging from two to 52 deaths per household. More than three quarters had at least four small ruminants with diarrhoea, and more than three quarters had at least two cases of respiratory disease (Fig. 4A). Pastoralists in Gursum reported lower numbers of mortality and morbidity in small ruminants, and half of the mixed crop-livestock households had either no change or an increase (Fig. 4A). Taking pastoralist households in both districts together, the median number of deaths, diarrhoea and respiratory disease was 0.45, 0.32 and 0.18, respectively.

Post-intervention, several pastoralists from both study districts reported fewer deaths and disease (Fig. 4A). The average household in Awash Fentale experienced a reduction of five fewer small ruminants dying, ranging from up to 38 fewer deaths to 21 additional small ruminant deaths after the intervention. Three quarters of households had a reduction of at least one death post-intervention (Fig. 4B). Taking pastoral households in both districts together, the median number of deaths, diarrhoea and respiratory disease was 0.06, 0.08 and 0.01, respectively.

Comparing the number of events pre- and post-intervention, the poisson model showed that pre-intervention, pastoralists had a 2.4 times higher rate of small ruminant deaths, a 1.65 times higher rate of diarrhoea, and a 2.35 times higher rate of respiratory disease. For mixed crop-livestock households, pre-intervention had a 4.71 times higher rate of small ruminant deaths, a 7.45 times higher rate of diarrhoea, and a 4.23 times higher rate of respiratory disease (Supplementary material). In all models, the effect of intervention was statistically significant ($p < 0.05$); the effect of the intervention was significantly larger in mixed systems compared to pastoralist systems (p-value of the likelihood ratio test comparing the poisson model with interaction (system*intervention) to the model without the interaction term was < 0.05 for all outcomes).

4. Discussion

With the pressures of climate change and recurrent drought affecting grazing and water resources, small ruminant and camel production are becoming increasingly appealing (Menghistu et al., 2021). And yet the production constraints for these species are under-reported. The YSMRC project was undertaken to identify and evaluate interventions to reduce young stock mortality in major production systems in Ethiopia. The intervention packages selected for small ruminants and camels (and cattle, previously described (Wong et al., 2022) were successful in

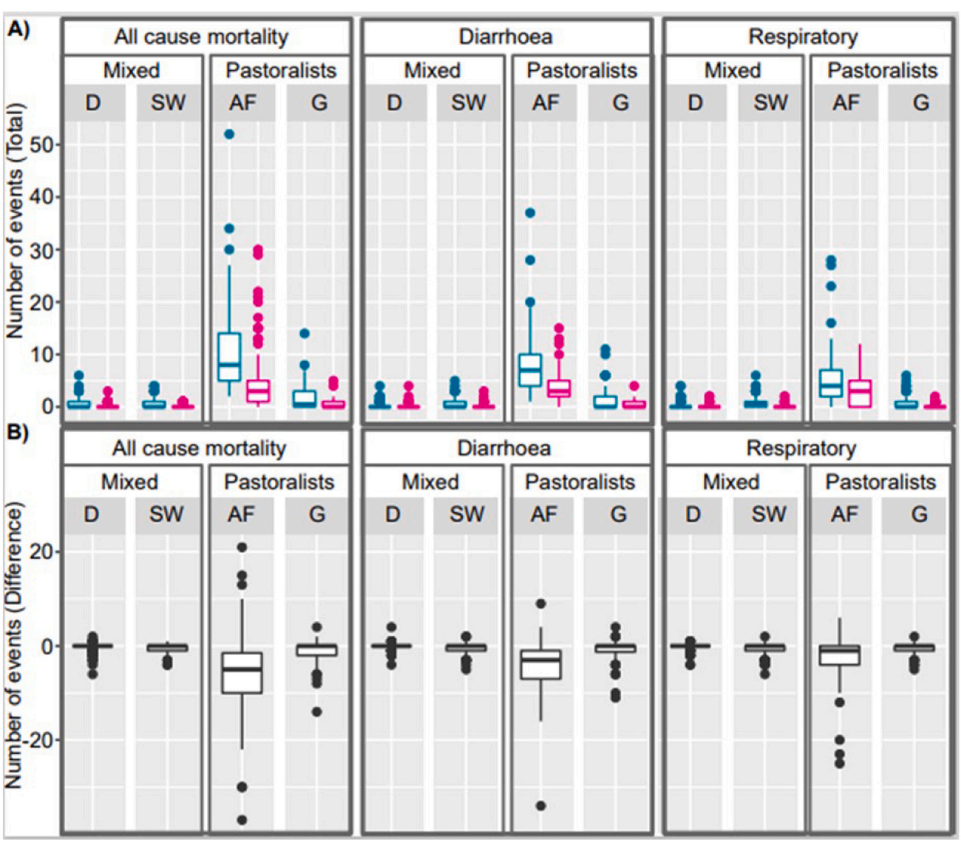

Fig. 4. a) Box and whisker plots showing number of deaths and cases of diarrhoea and respiratory disease in small ruminants for both production systems, and each district. Baseline measures are represented in blue and final evaluation represented in red. b) Box and whisker plots showing change post-intervention in mortality and cases of diarrhoea and respiratory disease in small ruminants for both production systems, and each district. T = total; D = Dalocha; SW = Siyadebere & Wayou; AF = Awash Fentale; G = Gursum.

significantly reducing the prevalence of young stock mortality, diarrhoea, respiratory disease, and (in camels) death from malnutrition. The interventions included a range of basic health and husbandry practices, selected by local and visiting experts, and did not require advanced technologies. As such, they could be relatively straightforward, cost-effective and impactful if implemented on a broader scale. However, there were many interventions and different interventions had different levels of uptake in different areas of pastoral production. Therefore, scoping studies are recommended for future applications to ascertain a) what pastoralists are already doing in any particular area, b) what pastoralists and local livestock experts think would be most useful to implement, c) how many additional interventions pastoralists would be willing and able to perform, in order to select appropriate interventions for new areas, and d) evaluate the interventions with cost-benefit analyses.

Generally, pastoralists experienced higher small ruminant mortality (median 0.45) and disease prevalence (median 0.32 diarrhoea and 0.18 respiratory disease) compared to mixed crop-livestock smallholders (median 0, 0 and 0, respectively). The rate ratio of the effect of the intervention was significantly higher in mixed herds than in pastoralist herds; however, because pre-intervention pastoralists had higher morbidity and mortality and a higher number of small ruminants, the intervention had a greater effect in increasing the number of healthy young stock in pastoralist herds. Similarly, within the pastoralist system, herds were typically larger in Awash Fentale than Gursum, with the effect of intervention higher in Awash Fentale. However, despite the overall success of the interventions, not all households benefitted, with a few households reporting increased mortality and morbidity. This is a concern, especially for those pastoralists with very few animals, or those with very low mortality pre-intervention, where no improvements in mortality, or indeed increased losses during the period of the interventions would lead one to interpret the interventions as a failure. Only over a longer period would benefit be expected, but this would require investment which would be unlikely to occur if the interventions were not already seen as beneficial.

This latter outcome likely also relates to the main limitation of the study, in that it was conducted over a single year, without a control group (deemed unworkable in the study design). Although there was not much difference with respect to climate between the years, the between-year effects could not be accounted for in the changes observed. Additionally, the contribution of each individual factor is difficult to ascertain as the interventions were implemented in a combined package rather than individually, and only a selection of camel and no small ruminant interventions were monitored. Many households had very few animals which made it challenging to measure impact. Furthermore, the contribution of the different management improvements to a decreased mortality might have varied depending on the area; in pastoralist areas in particular, the environment could have played a role in feed availability and animal survival, however the weather differences between the previous year and the study year were unremarkable. Flooding in early 2020 in Ethiopia was considered the most severe in a decade (European Commission, 2020), but flooding in the Awash River basin is a common occurrence (Achamyeleh, 2003; Wondim, 2016) and pastoralists local to this region may already practice adaptation strategies. The improved management of the interventions might have reduced the environmental influences by producing more resilient young animals.

Broadly similar findings have been reported in the limited published literature, with mean mortality rates of 14.9–33.5 % in lambs (Fentie et al., 2016; Hadgu et al., 2021) and 17.6–50 % in kids (Debele et al., 2013; Dereje et al., 2015; Fentie et al., 2016; Mayberry et al., 2018), and respiratory disease in lambs and gastrointestinal disease in kids the most common causes of morbidity (Tifashe et al., 2017). Ahmed and Hedge (2007) observed similar camel mortality (39 %) to our study, but a lower mortality due to pneumonia (7 %). Also similarly, malnutrition has also been found to contribute to mortality in camel calves (Fentie et al., 2016), and diarrhoea has been reported as the predominant cause of morbidity in camel calves (Abraha et al., 2019; Ahmed and Hedge, 2007; Gebru et al., 2018). Keskes et al. (2013) reported high disease prevalence to be the predominant cause of camel calf mortality, with camel pox, trypanosomiasis, diarrhoea and respiratory disease the most common diseases. A recent scoping review looked at interventions used to reduce morbidity and mortality in ruminants in sub-Saharan Africa (including 17 studies in Ethiopia), reporting vaccination, parasite control, antimicrobials, surveillance and feed supplementation (Nuvey et al., 2022). The review highlighted the scarcity of such studies (12 studies describing interventions in goats, four studies in mixed small ruminants and two studies in sheep). A simulated intervention study reported high mortality rates in Ethiopian goats even after improved healthcare interventions were implemented, but did show that improving nutrition reduced mortality rates (Mayberry et al., 2018).

Provision of colostrum to camel calves was reported to be practiced by the most households with no change due to optimal practice. There is very little information on camel management practices in Ethiopia (Awoke et al., 2015; Awoke and Ali, 2015), however, poor management of camel calves has been observed, including restricted colostrum feeding, despite pastoralists being aware of the requirement (Awoke et al., 2015; Awoke and Ali, 2015). It has been suggested that changes in colostrum management could reduce camel calf mortality considerably (Kaufmann, 2000). The largest improvement in practice was seen in the use of camel calf supplementary feed. Before this intervention, deaths due to malnutrition were 15 times higher, with 1.1 deaths pre-intervention and 0.07 post-intervention. Poor supplementary feeding has been observed previously, amongst other poor management practices (Fentie et al., 2016). Although poor management is considered a major cause of young stock mortality and morbidity, it is thought that farmers are aware of the challenges in managing young stock, but do not know how to address them (Fentie et al., 2016). The study found that most of the interventions monitored had good uptake, which should be considered a success, given than pastoralists will evaluate proposed management practices before adopting change (Kaufmann, 2000).

There were some conceptual and methodological limitations with the study. A large number of households were excluded from data analysis due to inaccuracies in pastoralist recall or enumerator error. Examples include where the number of animals born exceeded the possible number that the number of adult reproductive females could produce, or where the total number of animals born dead or alive, the number of stillborn animals, and the number of animals that died or lived did not ‘add up’. There is the potential for bias in the loss of these data, however we can only speculate on how this could affect the outcomes. Future field data collection could be improved by training enumerators to check data during interviews, or use of digital data collection tools with automatic checking. Many households had very few animals which made it challenging to measure impact. Another limitation is related to misclassification; farmers/pastoralists were asked to estimate morbidity and mortality during the previous year and during the follow-up period. Because of the intervention, farmers/pastoralists might have been more aware of young stock health and estimates from the follow-up year might have had increased validity.

Administrative support from all levels of the Ethiopian government was instrumental in the successful implementation of this project. Additionally, use of local language translations for SOPs, pastoralist training and data collection tools was important to pastoralists and helpful for enumerators. Involvement of the Animal Health Institute in the consortium helped with availability of laboratory diagnostic capability domestically and should aid the sustainability of the activity during scaling up. Some inputs for veterinary care and management were provided specifically by the study, such as weighing scales, drugs and drug delivery systems. These inputs facilitated the animal health care, however providing free veterinary drugs during scaling up would be challenging, as the cost has to be recovered. It is important to assess the financial cost and benefits of the interventions, and a cost-benefit analysis is presented in a poster by Kirk et al. at SVEPM 2023 (https://shorturl.at/jCFVW).

5. Conclusions

Targeted interventions for improving knowledge and uptake of basic animal husbandry, feeding and housing are recommended strategies for the reduction of morbidity and mortality in Ethiopian young stock. The pilot study findings demonstrated highly significant reductions in morbidity and mortality post-interventions, in camels and small ruminants. However, not all households benefitted from the intervention(s), with a few households reporting increased morbidity and mortality. These findings should inform future research and policy-making, and contribute to improved livestock productivity in Ethiopia. Indeed, the authors are aware that the activities from a wider study piloted are currently being scaled up for bovine calves by the MoA, and it is hoped that this will be extended to camel and small ruminant young stock as well.

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Authors contribution

Conceptualization, K.A., B.A., A.L., N.K. W.S. and T.F.; methodology and investigation, K.A., B.A., A.L., N.K., J.K.L., W.S., T.F., and M.D.; software, M.D.; validation and data curation, V.N. and J.T.W.; formal analysis, J.T.W and C.S.; resources, C.V., K.A., A.L., N.K., W.S., T.F. and A.P.; writing—original draft preparation, F.K.A., J.T.W., M.D., J.K.L. and C.S.; writing—review and editing, F.K.A., J.T.W., C.V., M.D., V.N., J. K.L, W.S., S.A., K.A., B.A., A.L., N.K., T.F., C.S. and A.R.P.; visualization, J.T.W. and C.S.; supervision, A.L., N.K., W.S., T.F. and A.R.P.; project administration, C.V., M.D., S.A., B.A., A.L., N.K., J.K.L., W.S. and T.F.; funding acquisition, K.A., N.K., W.S., T.F. and A.R.P. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest: Neither USAID nor the Bill & Melinda Gates Foundation played a role in the study design, data collection and analysis, decision to publish, nor preparation of the manuscript, however the MoA was instrumental in study design and data collection, and some authors are employed by the MoA or other Ethiopian government institutions.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2023.106005.

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