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Survival analysis for estimating lamb survival up to weaning in Harnali sheep

Parth Gaur, Z.S. Malik, Yogesh C. Bangar, Ankit Magotra and Ashish Chauhan

Department of Animal Genetics and Breeding, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India 125001

Research Article

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Author for correspondence:
Yogesh C. Bangar. Department of Animal Genetics and Breeding, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India 125001.
E-mail: yogeshbangar07@gmail.com

Summary

The present study was carried out to estimate lamb survival (in days) from birth to weaning under survival analysis using data records from 2057 Harnali lambs born to 134 sires and 623 dams between the period from 2001 to 2020. The weaning age in resourced population was 90 days from birth. The hazard ratio in terms of risk of death up to weaning was determined using Cox proportional hazards model by subjecting some fixed factors such as year of birth, sex of lamb, birth weight (kg), dam's weight at lambing (kg) and dam's age at lambing (years). The overall survivability up to weaning among lambs was 91.59% and Kaplan–Meier estimates of mean survival time up to weaning was 85.77 days. Cox proportional hazard modelling revealed that the hazards of death up to weaning was higher in male lambs [1.66, 95% confidence interval (CI): 1.22–2.26] compared with female lambs [hazard ratio (HR) = 1.00]. It was also observed that the hazards of death (HR = 0.91, 95% CI: 0.88–0.94) had decreasing trends over years. For birth weight (kg), hazard rate was 0.34 (95% CI: 0.25–0.46), which indicated that the risk of pre-weaning mortality was lower as birth weight increases. The weight and age of dams at lambing did not influence the survival time of studied population. The present findings indicated that survival time increased in studied lambs over the years and it could be increased more by giving more emphasis on better litter weight and general health aspects at farm level.

Introduction

Lamb survival is a very critical component in sheep production system that could immensely adversely affect the genetic improvement, animal welfare and economic issues of sheep breeding (Mukasa-Mugerwa *et al.*, 2000; Cloete *et al.*, 2009; Hatcher *et al.*, 2010; Abdelqader *et al.*, 2017). Lamb survival is not only important for economic purposes in sheep production, but survival is the function of health and reproductive traits such as fertility and mothering ability (Khanal, 2016). Several factors such as age and body weight of the dam, sex, and birth weight of lamb, type of birth, year and month of birth, and rearing system could affect the lamb survival (Morris *et al.*, 2000; Mandal *et al.*, 2007; Sawalha *et al.*, 2007; Vatankhah and Talebi, 2009; Lima *et al.*, 2019).

Survival analysis was applied to study of time and occurrence of death in animals and is different from other models in terms of nature of dependent variables as time and scope for adjustment of censored records. Censored records represent animals that had not died and were either sold or dead or still alive during the study period. Therefore, it differs from logistic regression that is also commonly used to study animal survival but for categorical outcomes (Southey *et al.*, 2001; Abdelqader *et al.*, 2017). Survival analysis provides the risk of death in an individual after a particular time and also estimates the hazard function for studying the risk of dying in a particular group against the other group (Bangar *et al.*, 2016). This method has been used in survival evaluations of beef (Martinez *et al.*, 2005), sheep (Conington *et al.*, 2001) and swine (Serenius and Stalder, 2004). It evaluates factors that have a changing influence on survival as the length of exposure to that factor increases. Therefore, survival analysis is the method of choice, as it not only tells us about the mortality of the lambs, but it also tells us about the various hazards to survive as well as the actual number of days that animals survived.

Therefore, the present study was carried out to perform survival analysis using Cox proportional modelling for estimating the lamb survival time up to weaning by determining the effects of various factors in Harnali lambs.

Materials and Methods

Study area

The present research work was undertaken at Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, Haryana, India (29°08′N latitude and 75°41′E longitude). Harnali is a superior carpet wool produced by a sheep breed developed by Lala Lajpat Rai University of

Veterinary and Animal Sciences, Hisar. Harnali sheep are a three-breed cross of 37.5% Nali and 62.5% exotic inheritance (Russian Merino and Corriedale).

Feeding and management

The feeding and management practices that were followed were more or less uniform throughout the year. The animals were let loose for grazing in pasture, harvested fields and the surrounding area of farm in daytime (for ~6 h effectively daily on natural pastures). Apart from grazing, all animals were fed with green and dry fodder in the morning and evening as per the requirements. In addition to this, a definitive quantity of concentrates was also fed to all animals in the evening. The ewes were mated usually in the months of September and October and lambs were born in late February to March. The ewes after lambing were kept along with lambs in lambing pens for 1 week and suckling of lambs twice in a day (morning and evening) up to weaning was practised. A good quality concentrate mixture was also provided to lambs in addition to suckling. The lambs whose dam had died in the early period were given special artificial rearing including milk from another ewe. After 1 week of age, lambs were shifted to another pen (ewes with lambs of 0 to 3 months). The weaning period for lambs was typically 90 days of age. All the lambs were ear tagged at birth within 2–3 days of lambing for identification.

Data collection

Historical data records were used from pedigree sheets of 2057 Harnali sheep maintained at the Department of Animal Genetics and Breeding, College of Veterinary Sciences, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar for the period January 2001 to December 2020. The lambs records including birth date, birth weight (kg), sex, dam's age at lambing (years), dam's weight at lambing (kg) and date of death were taken from inventory and death registers.

The survival time of lambs up to weaning age (in days) was calculated from date of birth to date of death or end of study period. The lambs that were sold or culled during the particular study period were considered as censored observations. The lambs that were alive at the end of study period were also considered as censored observations. For censored lambs that were alive at the end of each study period, the survival time was considered the last day of the study period. All censored lambs were coded as 0 and remaining lambs that died during study period were coded as 1.

Statistical analysis

Descriptive statistics were performed to calculate the lamb survivability (%) up to weaning age. Kaplan–Meier estimates (Kaplan and Meier, 1958) of survival function were obtained to understand the mortality pattern with consideration of censored data. Then mean survival time was calculated for each survival period.

To study the effects of various factors on survival of Harnali lambs, the Cox proportional hazard model was used in the study. This model estimates the hazard (or risk) of death for an individual after adjustment for other explanatory variables. The hazard function that gives the instantaneous death rate for lamb 'i' at survival time 't' is given as:

$$h_i(t) = h_0(t)\ \exp(b_i X_i)$$

where $h_i(t)$ represents the instantaneous death rate at time t of the i^{th} lamb; $h_0(t)$ represents baseline hazard function; b_i represent the proportional change that can be expected in the hazard due to fixed effects; x_i represent fixed effects such as year of birth, sex, birth weight, dam's weight at lambing and dam's age at lambing. The ratio of $h(t)/h_0(t)$ is the hazard ratio that provides an estimate of the risk per unit change in the explanatory variables relative to the baseline hazard function (Collett, 2003). All statistical analyses were carried out using IBM SPSS Statistics 23 software. A graphical representation of estimated survival functions was also made using the same software.

Table 1. Data structure of survival records in three study periods of Harnali sheep

Trait	Statistics
No. of records	2057
No. of death up to weaning (90 days)	173 (8.41%)
Pre-weaning survivability (%)	91.59
Censored observation (sold prior weaning)	21 (1.02%)
Year of birth	2001 to 2020
Sex of lambs	Male/Female
Mean ± SE for birth weight (kg)	3.35 ± 0.59
Mean ± SE for dam's weight at lambing (kg)	29.45 ± 4.03
Mean ± SE for dam's age at lambing (years)	4.27 ± 1.94
Kaplan–Meier estimates for mean survival time (days)	85.77 ± 0.35

Table 2. Survival analysis using Cox proportional hazards model subjected to various factors in Harnali lambs

Factor	Hazard rate	95% confidence interval	*P*-value
Year of birth	0.91	0.88, 0.94	<0.001
Male lambs (reference: female)	1.66	1.22, 2.26	<0.001
Birth weight (kg)	0.34	0.25, 0.46	<0.001
Dam's weight at lambing (kg)	1.00	0.95, 1.04	0.91
Dam's age at lambing (years)	1.05	0.98, 1.13	0.16

Results

The results of descriptive statistics and survival analysis for lamb survivability up to weaning age are shown in Table 1. In total, 173 Harnali lambs died out of 2057 lambs born during 2001 to 2020 year, which led to lamb survivability of 91.59% in the resourced population. The number of censored observations as lambs sold up to weaning was 21 (1.02%). The mean survival time for lambs up to weaning age was calculated as 85.77 days.

The results of Cox proportional hazard modelling indicated that year of birth, sex of lamb and birth weight have significant ($P < 0.001$) effects on lamb survivability up to weaning age (Table 2). However, dam's weight and age at lambing were a non-significant ($P > 0.05$) influence on lamb survivability up to weaning stage. The risk of death was estimated as hazard rate. A hazard rate < 1 indicates a lower risk of death. The hazard rates

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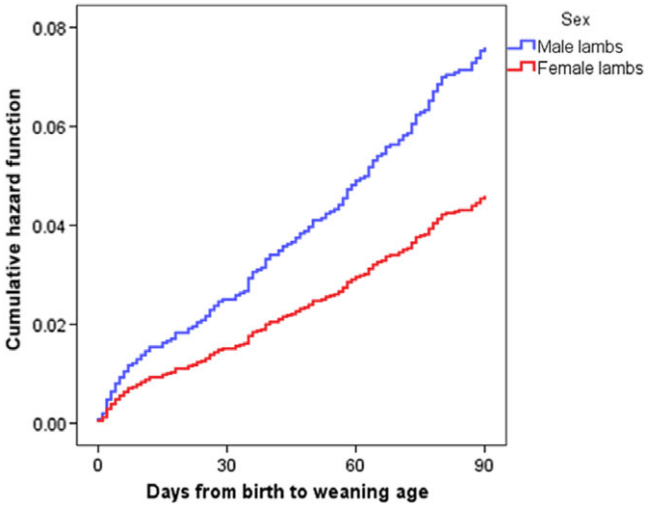

Figure 1. Estimates of hazard function for male and female lambs from birth to weaning age in Harnali lambs.

were observed to significantly decrease over the years (0.91, 95% CI: 0.88–0.94). It was higher in male lambs (hazard rate = 1.66; 95% confidence interval (CI): 1.22–2.26) compared with female lambs (hazard ratio = 1.00). For birth weight (kg), the hazard rate was 0.34 (95% CI: 0.25–0.46), which indicated that the risk of pre-weaning mortality was lower as birth weight increased.

The hazard function was generated for male and female lambs under Cox proportional modelling (Figure 1). The hazard function estimates the probability of death on a particular day from birth up to weaning. It was revealed that that the male lambs had a higher risk of death than female lambs.

Discussion

The present study focused on estimating pre-weaning survival time in Harnali lambs using the Cox proportional modelling under survival analysis. This is different than estimating survival under logistic regression because Cox proportional modelling considers actual survival time (in days) instead of binary counts (died/alive). Therefore, it has advantages over logistic regression to determine the probability of survival at particular time points. Additionally, Southey *et al.* (2001) reported that the estimates due to survival analysis had a lower standard error than logistical analysis.

The present study not only included survivability (%) but also calculated mean survival time (in days) for different periods of study. The observed lamb survivability in the study was higher than the estimates of Mandal *et al.* (2004), Hatcher *et al.* (2009), Brien *et al.* (2014) and Tesema *et al.* (2020), but was lower than the Barazandeh *et al.* (2012) and Bangar *et al.* (2016) results. Mean survival time was found to be lower than for the study of Bangar *et al.* (2016).

The significant effect of the year of birth on life length, survival rate and hazard ratios in all ages to yearling found in this study were in general agreement with reports by Berhan and Van Arendonk (2006) and Mandal *et al.* (2007). The decreasing trends of pre-weaning deaths over years might be due to better managemental practices and also it may be the result of selection of superior animals under breeding plans. The sex of lambs affected survival of the lamb with leading hazards of death for male than female lambs. The higher risk of mortality in male lambs versus female lambs has also been reported by several authors (Southey *et al.*, 2001; Sawalha *et al.*, 2007; Vatankhah and Talebi, 2009; Everett-Hincks *et al.*, 2014; Bangar *et al.*, 2016).

The present findings of non-significant effects of dam age at lambing was contrary to previous reports by Morris *et al.* (2000) and Sawalha *et al.* (2007) who reported higher lamb mortality in younger ewes than older ewes. Furthermore, it was contrary to reports by Cloete *et al.* (2009) and Southey *et al.* (2001) who reported that lamb survival improved with ewe age. The present study also reported non-significant effects for dam weight at lambing on lamb survival up to weaning that might be due to confounding effects of it with birth weight.

The significant effect of birth weight on survival of lamb was estimated using the Cox proportional hazard model and indicates that the birth weight was the priority criteria for survival of lambs in the initial days (Schreurs *et al.*, 2010; Oldham *et al.*, 2011). A low lamb mortality was associated with high birth weight in the present study and similar effects of birth weight on lamb survivability have been reported elsewhere (Morris *et al.*, 2000; Holst *et al.*, 2002; Mandal *et al.*, 2007; Sawalha *et al.*, 2007). These findings indicated that the present management practices need to be oriented towards obtaining higher litter weights by providing extra nutrition to advanced pregnant ewes and good care of young ones.

In conclusion, survival analysis in Harnali lambs aged from birth to weaning age was performed using actual time (in days) as a dependent variable. The results indicated that the lamb survival time had significant and positive association with years and birth weight of lambs. However, male lambs showed a higher risk of pre-weaning deaths than female lambs. The dam's age and weight had no significant effect on survival time. It was concluded that attention to better managemental practices is necessary to improve lamb survival in the early stages of life.

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