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Study of Factors Affecting Longevity and Survival of Iranian Guilan Sheep Using Linear and Non-Linear Models

Research Article

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ABSTRACT

The objective of this study was to evaluate non-genetic factors affecting longevity and survival of Guilan sheep from birth to yearling. Longevity and survival records of 41037 lambs born from 496 rams and 10256 ewes of Guilan sheep were analyzed using linear and Weibull models. Results indicated that the overall mean of longevity was 1260.84 days. The fixed effects of flock, dam age, sex, year and month of birth and interaction between dam age-sex had significant effects on longevity ($P<0.05$). But birth type, birth weight and interactions of sex-birth type and dam age-birth type had no significant effect on longevity ($P>0.05$). Male lambs had lower survival and greater hazard ratio compared with female lambs. Lambs which born in recent years and last months of year had greater hazard ratios and lower survival in the period from birth to 2-months and birth to yearling. Lambs which born in early months of year had greater survival and lower hazard ratio than those birth to 3, 6 and 9 months of age. Although twin lambs had lower survival and greater hazard from birth to 2 and 3 months of age periods, difference of single and twin lambs was not significant in other time periods. In conclusion, linear and non-linear models can be used to study the survival of lambs and it's possible to improve this important item through modifying non-genetic factors.

KEY WORDS culling, fat tailed sheep, hazard ratio, lifetime, non-genetic factors.

INTRODUCTION

Lamb survival is one of the most important factors affecting the income of sheep flocks (Southey *et al.* 2001). Despite economic importance of lamb survival, lower attention was paid to this trait in different sheep breeds. Identification of environmental factors affecting longevity and survival and estimation of genetic parameters for these traits are necessary for incorporating these in breeding programs and their genetic improvement (Vatankhah *et al.* 2009). Mortality of lambs is a complex event that affected by environmental factors such as climate, nutrition, management, diseases, infectious agents and non-genetic factors such as birth year, age and body condition of dam, birth type, sex and birth weight of lamb and lamb genetic (Mandal *et al.* 2007; Riggio *et al.* 2008). Lamb mortality rate from birth to yearling in different sheep breeds and different climate conditions reported to be from 5 to 59% which often occurs in early ages of lambs at a time when environmental changes are extreme for both ewe and lamb (Yapi *et al.* 1990; Green and Morgan, 1993; Nash *et al.* 1996; Mukasa-Mugerwa *et al.* 2000; Sawalha *et al.* 2007). Management practices that provide adequate care and avoid the spread of disease tend to promote higher survival rates from birth to yearling age. Survival of lambs improve along with increasing ewe age (Southey *et al.* 2001; Sawalha *et al.* 2007), although decreases in survival of lambs born to ewes greater than five year of age were observed (Brash *et al.* 1994; Morris *et al.*

2000). The risk of death at birth for single lambs is higher compared to lambs born in multiple litters, but the risk of death was greater for multiple born lambs after one day postpartum, because the birth weight of single lambs is higher than twin lambs and they have higher dystocia probability. Higher rates of survival initially associated with increases in birth weight until birth weight eventually reaches a level associated with increased dystocia. Therefore, the birth weight has quadratic relationship with survival of lambs. Many studies reported optimum birth weight range for lamb survival (Lopez-Villalobos and Garrick, 1999; Morris *et al.* 2000; Sawalha *et al.* 2007; Smith, 1977). In recent decades, many attempts have been made to identify the key factors involved in lambs' mortality, but the results are varied and influenced by breed, production system and models used for analyses. Lambs survival until particular age can be analyzed as continuous or discrete trait. In discrete situation, survival analyzed as a binary trait (alive 0 and dead 1). This approach may exclude a considerable amount of data in removal date because censored records are not included (or imperfect data includes records from individuals that have not yet been removed from the system at the time of evaluation, however, uncensored survival or complete data refers to records from those individuals that have been removed prior to the date of evaluation). Use of binary data for survival is beneficial if more continuous measures of removal time are not available (Brash *et al.* 1994). Discrete survival data often has been evaluated with linear models even though linear methods ignore the discrete nature of the trait (Borg, 2007). The age or time when an individual leaves the production system considered as longevity. Continuous measures of time, such as days between birth and death (longevity) or days between first parturition and disposal or death (length of productive life) can be included in genetic evaluations for survival (Conington *et al.* 2001). But animals which not remove yet, can not be used in the analysis. In this condition, the use of non-linear models such as survival analyses with proportional hazards models are superior because they account for non-normal distributions and appropriately incorporate censored data and time-dependent effects on survival to better account for environmental factors (Borg, 2007). The objective of the present study was to evaluate non-genetic factors affecting longevity and survival of Guilan sheep from birth to yearling using linear and non-linear models.

MATERIALS AND METHODS

Data origin

In the present study, the longevity and survival records of 41037 lambs born from 496 rams and 10256 ewes of Guilan sheep were used which were collected by the Agricultural Jahad Organization of Guilan province in Iran from 1990 to 2013. Birth of lambs in the flock occured during initial days of December to the last days of April. For each lamb, birth information including sex and birth type (single or twin) was recorded. Also, the removal/death date and its reason were recorded for dead or culled lambs. In this study, one censor code (zero or one) was determined for survival of any lambs in a given age (any survival record included two items of removal age and censor code).

For calculating lifetime or longevity, birth date subtracted from removal date. Studied traits included cumulative survival from birth to 2, 3, 6, 9 and 12 months of age. For determining cumulative survival from birth to yearling, longevities of lambs from birth to 60 (S1), 90 (S2), 180 (S3), 270 (S4) and 365 (S5) days of age were categorized in five different classes which considered as separate traits. Censor code 0 was given for lambs that have not yet been removed from the flock at the month of evaluation (such as 2 months of age). Conversely, censor code 1 referred to records from those lambs that have been removed for reasons associated with poor fitness prior to the date of evaluation. For individuals that deleted for any reason other than death, days of lamb longevity presented and censor code defined as 0, even the longevity of lamb was lower than evaluation month (Borg, 2007).

The Microsoft Visual Fox pro 8.0 program was used for data editing. Linear and non-linear models were used to study the effects of non-genetic factors on lamb longevity and survival.

Statistical analyses

Linear model

The GLM procedure of SAS 9.1 program was used for identifying non-genetic factors affecting lambs' longevity (SAS, 2003). The following model was used in the analysis:

$$Y_{ijklmno} = \mu + H_i + R_j + M_k + S_l + BT_m + P_n + b1(BW_{ijklmno} - \overline{BW}) + (P\times S)_{nl} + (P\times T)_{nm} + (S\times BT)_{lm} + e_{ijklmno}$$

Where:
$y_{ijklmno}$: longevity records.
μ: overall mean.
H_i: fixed effect of i^{th} flock (i=1,2,…,41).
R_j: fixed effect of j^{th} birth year (j=1,…,24).
M_k: fixed effect of k^{th} month of birth (k=1,…,12).
S_l: fixed effect of l^{th} sex of lamb (l=1, 2).
BT_m: fixed effect of m^{th} birth type (m=1, 2).
P_n: fixed effect of n^{th} dam age on year scale (n=2,…,7).
$BW_{ijklmno}$: birth weight as covariate.
$\overline{BW}$: average birth weight.

$e_{ijklmno}$: random residual error.

Survival analysis model

The LIFREG, LIFTEST and PHREG procedures of SAS (2003) program were applied for identifying non-genetic factors affecting cumulative survival traits from birth to yearling using the following model:

$$(Y \times S)_{ijklmo} = \mu + H_o + A_i + B_j + T_k + S_l + M_m + b_1(W_{ijklmno} - \overline{W}) + b_2(W_{ijklmno} - \overline{W})^2 + e_{ijklmo}$$

Where:
Y_{ijklmo}: age at failure (death or censoring).
S_{ijklmo}: censor code of 0 or 1.
μ: overall mean.
H_o: fixed effect of o^{th} flock (o=1,2,…,41).
A_i: effect of i^{th} age of dam on year scale (i=2,…,7).
B_j: fixed effect of j^{th} birth year (j=1,…,24).
T_k : fixed effect of k^{th} birth type (single and twin).
S_l: fixed effect of l^{th} sex of lamb (male and female).
M_m: fixed effect of m^{th} month of birth (December, January, February, March, April); b_1; quadratic regression coefficients on lamb birth weight and b_2; linear and quadratic regression coefficients on lamb birth weight.
W_{ijklmo}: birth weight of lambs.
$\overline{W}$: average birth weight.
e_{ijklmo}: random residual error.

The non-linear survival model can be written as the following hazard function:

$$h(t,\chi_i) = h_0(t) \times \exp(\chi_i' \beta)$$

Where:
$h(t,\chi_i)$: instantaneous death rate at time t of a particular animal i characterized by a set of explanatory variables χ_i (age of dam, birth year, birth type, sex of lamb, lamb birth month, linear and quadratic effects of birth weight) and can be written as the baseline hazard function $h_0(t)$ multiplied by the exponential effect (β) of x_i variables.

The baseline hazard function $h_0(t)$ has Weibull distribution, with scale parameter λ and shape parameter ρ as follows:

$$h_0(t) = \lambda p(\lambda p)^{p-1}$$

Where:
$(\lambda t)^{\rho-1}$: hazard of culling at time t and because parameters (β) estimated on normal logarithm scale, hazard ratio for different levels of factors was calculated as follows:

$$HR = e^{-\beta/P}$$

RESULTS AND DISCUSSION

Results obtained from the analysis of lambs' longevity are presented in Table 1. Hazard ratios and their significance for fixed effects on survival traits (S1 to S5) are shown in Table 2.

Table 1 Least squares means and their standard errors for different fixed effects affecting longevity

Effect	Level	Lsmeans±SE
Dam age (year)	2	627.92±21.01[f]
	3	701.23±25.82[e]
	4	983.08±29.84[d]
	5	1313.23±47.30[c]
	6	1663.55±85.99[b]
	7	2625.93±91.24[a]
Sex	Male	931.94±27.96[b]
	Female	1048.56±25.89[a]
Month of birth	8	973.50±187.50[e]
	9	2303.07±175.08[a]
	10	1193.54±37.64[c]
	11	856.91±28.05[f]
	12	834.03±41.38[f]
	1	1081.37±172.94[d]
	2	1375.35±51.37[b]
Litter size	Single	1012.07±20.09[a]
	Twin	1039.53±152.81[a]

Different letters in each column for each level indicated significant differences (P<0.05).

Also, hazard ratio estimates and their standard errors for different factors affecting different survival traits are shown in Tables 3, 4, 5, 6 and 7. The results of survival analysis indicated that effect of non-genetic factors including flock, birth month, birth year, lamb sex and birth weight of lambs were significant on survival especially for early ages (P<0.05). But effect of dam age was not significant on survival in all age periods from S1 to S5 (P>0.05).

Effect of dam age on survival was not significant (P>0.05), but its effect was significant on longevity (P<0.05). The greatest average of longevity was for lambs that born from dams with 6 and 7 years of age and lambs born from dams with 2 years of age had minimum longevity. Therefore, lambs with higher longevity had older dams. Difference between maturity degrees of ewes can be the reason of significant effect of dam age on longevity. In agreement with the results of present study, Smith (1977) reported that yearling ewes had lambs with lower vigor and higher mortality rates than lambs from older ewes. But, Barazandeh *et al.* (2012) did not find significant effect of dam age on mortality in Iranian Kermani sheep. Also, consistent with the current results, Ramezani Akbar Abad and Ghavi Hosseein-Zadeh (2015) reported effect of dam age on longevity in Iranian Mehraban sheep.

Table 2 Hazard ratios and their significance for fixed effects on survival from birth to yearling age

Effect	S1	HR	S2	HR	S3	HR	S4	HR	S5	HR
Flock	*	1	*	1	*	1	NS	1	*	1
Birth year	*	1.29	*	1.14	*	1.11	NS	1.04	NS	1.05
Birth month	*	1.06	*	0.72	*	0.66	*	0.59	*	2.41
Lamb sex	*	1.82	*	1.68	*	1.68	NS	1.24	*	1.68
Birth type	*	0.54	*	0.81	NS	0.83	NS	1.03	NS	1.59
Birth weight	*	1.45	NS	0.93	NS	0.94	NS	1.58	*	0.62

S1: cumulative survival from birth to 2 months; S2: cumulative survival from birth to 3 months; S3: cumulative survival from birth to 6 months; S4: cumulative survival from birth to 9 months; S5: cumulative survival from birth to yearling and HR: hazard ratio.
* (P<0.05).
NS: non significant.

Table 3 Estimates of hazard ratios and their standard errors for effects of flock, year of birth, month of birth, sex, litter size and birth weight on cumulative survival from birth to 2 months of age (S1) obtained from Weibull survival model of analysis

Variable	Parameter estimate	Standard error	Chi-square	P-value	Hazard ratio
Flock	-0.0003462	9.90549E-6	1221.4580	< 0.0001	1.000
Year of birth	0.25982	0.00691	1414.5016	< 0.0001	1.297
Month of birth	0.06075	0.00908	44.7894	< 0.0001	1.063
Sex	0.60196	0.07102	71.8347	< 0.0001	1.826
Litter size	-0.60154	0.06112	96.8627	< 0.0001	0.548
Birth weight	0.37457	0.02426	238.3942	< 0.0001	1.454

Table 4 Estimates of hazard ratios and their standard errors for effects of flock, year of birth, month of birth, sex, litter size and birth weight on cumulative survival from birth to 3 months of age (S2) obtained from Weibull survival model of analysis

Variable	Parameter estimate	Standard error	Chi-square	P-value	Hazard ratio
Flock	-0.0001893	0.0000327	33.5897	< 0.0001	1.000
Year of birth	0.13120	0.02278	33.1853	< 0.0001	1.140
Month of birth	-0.31689	0.06361	24.8165	< 0.0001	0.728
Sex	0.51924	0.14301	13.1835	0.0003	1.681
Litter size	-0.20865	0.29048	0.5160	0.4726	0.812
Birth weight	-0.07124	0.10377	0.4713	0.4924	0.931

Table 5 Estimates of hazard ratios and their standard errors for effects of flock, year of birth, month of birth, sex, litter size and birth weight on cumulative survival from birth to 6 months of age (S3) obtained from Weibull survival model of analysis

Variable	Parameter estimate	Standard error	Chi-square	P-value	Hazard ratio
Flock	-0.0001627	0.0000337	23.3706	< 0.0001	1.000
Year of birth	0.11172	0.02383	21.9841	< 0.0001	1.118
Month of birth	-0.40786	0.07002	33.9301	< 0.0001	0.665
Sex	0.52411	0.14613	12.8642	0.0003	1.689
Litter size	-0.18056	0.29219	0.3819	0.5366	0.835
Birth weight	-0.05703	0.10901	0.2738	0.6008	0.945

Table 6 Estimates of hazard ratios and their standard errors for effects of flock, year of birth, month of birth, sex, litter size and birth weight on cumulative survival from birth to 9 months of age (S4) obtained from Weibull survival model of analysis

Variable	Parameter estimate	Standard error	Chi-square	P-value	Hazard ratio
Flock	5.76943E-6	0.0000666	0.0075	0.9310	1.000
Year of birth	0.04733	0.05080	0.8679	0.3515	1.048
Month of birth	-0.52036	0.09221	31.8464	< 0.0001	0.594
Sex	0.22051	0.18507	1.4196	0.2335	1.247
Litter size	0.03076	0.33741	0.0083	0.9274	1.031
Birth weight	0.45828	0.16333	7.8724	0.0050	1.581

Table 7 Estimates of hazard ratios and their standard errors for effects of flock, year of birth, month of birth, sex, litter size and birth weight on cumulative survival from birth to yearling age (S5) obtained from Weibull survival model of analysis

Variable	Parameter estimate	Standard error	Chi-square	P-value	Hazard ratio
Flock	-0.0001917	0.0000630	9.2549	0.0023	1.000
Year of birth	0.05521	0.04859	1.2909	0.2559	1.057
Month of birth	0.88186	0.16613	28.1769	< 0.0001	2.415
Sex	0.52058	0.19151	7.3892	0.0066	1.683
Litter size	0.46644	0.37245	1.5684	0.2104	1.594
Birth weight	-0.46785	0.18942	6.1001	0.0135	0.626

It was shown that lamb survival improved along with increase in dam age (Southey *et al.* 2001: Sawalha *et al.* 2007: Riggio *et al.* 2008); although Morris *et al.* (2000) showed slight decreases in survival of lambs born to ewes greater than 5 years of age. Also, Hatcher *et al.* (2009) reported non-linear relationship between age of dam and survival rate in Merino lamps, so that minimum survival rate observed in lambs from ewes with 2 and 6 years of age and beyond and maximum survival rate observed in lambs from ewes with 4 years of age and this rate significantly differed with other age groups. This is in contradiction with the results of present study.

Effect of birth type on longevity and S2, S3, S4 and S5 was not significant (P>0.05). But this item significantly affected on S1 (P<0.05). Maximum and minimum risks of death between single and twin lambs were for twin lambs in S5 and single lambs in S1, respectively. In general, twin lambs have lower birth weight and greater susceptibility to diseases compared with single lambs (Smith, 1977; Morris *et al.* 2000; Sawalha *et al.* 2007).

Smith (1977), Morris *et al.* (2000), Sawalha *et al.* (2007) and Ramezani Akbar Abad and Ghavi Hosseein-Zadeh (2015) indicated that survival of single and twin lambs did not significantly differ among different ages.

But similar to the current results, they showed that only S1 was affected by the birth type of lambs. Bahri Binabaj (2012), Hatcher *et al.* (2009), Southey *et al.* (2001) and Vatankhah (2012) reported that lambs born in twin litters had lower longevity and survival in all ages compared to lambs born as singles.

Birth year affected longevity and survival in S1, S2 and S3 (P<0.05), but effect of birth year was not significant on S4 and S5 (P>0.05). Study of survival indicated that lambs born in recent years have a greater risk of removal in all ages compared to lambs born in early years. Therefore, number of removed lambs increased along with progressing the birth year of lambs. The greatest hazard ratio of birth year was for S1 (1.29) and the least was for S4 (1.04).

Variation of rain, climate condition and also increase or decrease of forage in different years and sheep dependency to pasture can be considered as possible reasons for significant effect of year on the studied traits. The results of this study were consistent with the reports of Chniter *et al.* (2011) in Dyman sheep, Talebi and Edris (1998) in Lori-bakhtiari and Mohammadi *et al.* (2010) in Sanjabi sheep and were similar to the results of Vatankhah (2012) in Lori-bakhtiari sheep. But these results were in contradiction with the results of Ceyhan *et al.* (2009) in Sakiz sheep.

Mortality rate varies from one year to another, so that mortality in British flocks differs from 40 to 50% which could be related to climatic conditions.

Therefore, environmental factors such as birth season and year and rearing region could affect on mortality in the flock (Sawalha *et al.* 2007; Smith, 1977). Birth month significantly affected longevity (P<0.05). Lambs which born in December had the greatest longevity and lambs born in February and March had the least longevity. Also, birth month significantly affected on the survival of lambs (P<0.05). The most risks of culling were for S5 and S1, respectively and lambs born in February and March had greater risk of culling compared with early months of birth. With progressing birth months in the above mentioned age periods, culling risk increased and corresponding survival decreased. Whereas in the time periods related to S2, S3 and S4, lambs born in the last months of birth had lower culling risks and greater survivals compared to lambs born in early months of birth. The least culling risk was observed in S4. This result was similar to the results of Vatankhah (2012) in Lori-bakhtiari and Bahri Binabaj (2012) in Karakul sheep. Weak management in the last months of birth or pregnant ewes with inappropriate body condition which generate lambs with undesirable protection may be the reasons for decreasing longevity and survival of lambs and increase of culling risk in the last months of birth. Therefore, one of the non-genetic methods to improve the longevity and survival of lambs is to provide good management methods for ewes at mating season. Therefore, all or majority of ewes become pregnant in their first and second estrus with suitable body condition and produce lambs in the first and second months of lambing within the flock (December and January) (Vatankhah, 2012).

Lamb sex significantly affected longevity, S1, S2 and S3 (P<0.05), but had not significant effect on S4 (P>0.05). Least squares means of longevity for females was greater than male lambs. Results of present study was in agreement with the results of Barazandeh *et al.* (2012) in Kermani, Jafaroghli *et al.* (2010) in Moghani, Rashidi *et al.* (2011) in Kermani, Ceyhan *et al.* (2009) in Sakiz, Chniter *et al.* (2011) in Dyman, Talebi *et al.* (2010) in Lori-bakhtiari, Mohammadi *et al.* (2010) in Sanjabi and Bahri Binabaj (2012) in Karakul sheep.

Study of sex effect on survival indicated that male lambs tended to have higher culling risk and lower survival in all survival traits from birth to yearling. Most culling risk was for lambs in S1 which was consistent with the results of Bagheri (2010) in Lori-bakhtiari, Aslaminegad *et al.* (2011) in Baluchi, Hatcher *et al.* (2009) in Australian Merino, Riggio *et al.* (2008) and Sawalha *et al.* (2007) in Black face, Smith (1977) in American sheep, Chniter *et al.* (2011) in Dyman and Maxa *et al.* (2009) in Texel sheep. Later slaughter of male lambs compared to females can be the reason for higher culling rate in males.

Mandal *et al*. (2007) reported that unknown harmful Sex-linked gene was responsible for the higher mortality and culling rate in male lambs, whereas Iman and Slyter (1996) did not find significant effect of lamb sex on mortality. Birth weight had not significant effect on longevity (P>0.05), but this factor significantly affected S1 and S5 (P<0.05). Effect of birth weight on survival in other stages was not significant (P>0.05). Maximum and minimum hazard ratios of birth weight were observed for S4 and S5, respectively. Hence increase in the birth weight of lambs resulted in higher culling risk for lambs in the age periods related to S4 and S1, whereas lambs in other age periods had greater survival and lower culling risk.

CONCLUSION

From the results of linear models and survival analysis it can be seen that variables of flock, dam's age at lambing, lamb's sex, year and month of birth significantly affected on longevity. Flock, birth month, birth year, lamb's sex, type of birth and birth weight of lambs were non-genetic factors which significantly affected on S1 and effects of these factors were different by increasing lamb's age from S1 to S5. Generally effect of lamb's sex and birth month were significant on survival in most ages. It seems possible that the utilization of linear and non-linear models could be a suitable approach to improve survival by the identification of non-genetic factors. In consequence, making correct and practical decisions and creating a suitable breeding system could improve survival in the flocks.

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