
THE PROCEEDINGS OF THE
NEW ZEALAND SOCIETY
OF
ANIMAL PRODUCTION
VOLUME 62 2002

Effect of litter weight variation on cause of death and survival in triplet lambs

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ABSTRACT

Triplet litter weight variation and association with lamb death and ewe age was investigated. Litter weight percentage for each lamb was calculated (PLWT). The mean and standard deviation of PLWT were used to rank lambs as Light (<Mean - 1 standard deviation unit (SD)), Medium (Mean +/- 1 SD) or Heavy (>Mean + 1 SD). Average probability of viability at birth and death by dystocia or starvation exposure changed with weight rank. Viability at birth was Light 89.3%, Confidence interval (CI) 87.5% - 90.8%; Medium 95.6%, CI 95.1% - 96.1%; Heavy 98.0%, CI 97.4% - 98.5%, (P <0.001). Death due to dystocia was Light 8.9%, CI 7.2% - 10.8%; Medium 3.4%, CI 2.9% - 4.0%; Heavy 2.1%, CI 1.6% - 2.8%, (P <0.001). Death from starvation exposure was Light 5.9%, CI 4.8% - 7.4%; Medium 3.7%, CI 3.0% - 4.5%; Heavy 1.3%, CI 0.8% - 2.1%, (P <0.01). Ewe litter weight variation (EwePLVar) was calculated as weight range divided by total litter weight. Older ewes had less EwePLVar than two-year-old ewes (P <0.01). EwePLVar and average litter weight (AveLWT) affected litter survival (EwePLVar at birth, (P <0.001), birth to Day 3 (P <0.01). Average litter weight at birth (P <0.05), birth to Day 3 (P <0.01) and Day 3 to weaning (P <0.001)).

Keywords: triplet; survival; birth weight; weight variation.

INTRODUCTION

The number of triplet lambs born in New Zealand is increasing as the lambing percentage improves (Amer *et al.*, 1999). This is of concern because lamb mortality is higher in triplets than in twin and single lambs (Kerslake *et al.*, 2005), and has financial and welfare implications for commercial farmers. Research to investigate the reasons for the higher mortality in triplets is important so that animal breeding and farm management programmes can be adapted to improve triplet survivability. Previous studies have demonstrated that twin and triplet lambs which died before three weeks of age took at least twice as long to be born than twin and triplet lambs which survived. This prolonged parturition time was associated with death due to dystocia (Everett-Hincks *et al.*, 2007). In addition the generally lower birth weight of triplet lambs has been linked to an increased risk of death by starvation and exposure (Dwyer & Morgan, 2006). A study using 594 triplet lambs, Morel *et al.* (2008) reported the effects of weight distribution within triplet litters and showed that the mortality of a triplet lamb was influenced by the overall litter weight and not the birth weight of the individual. That is, a light lamb in a triplet litter has a higher mortality rate than a medium or heavy lamb, as determined by the lamb's weight as a proportion of the total litter weight and not its own birth weight Morel *et al.* (2008). Using the flock data collected for the Ovita lamb survival project the objectives of this paper were to confirm the effect of weight distribution on mortality within triplet litters, to determine the cause of death for triplet lambs of different weights within a litter which did not survive to three days of age, to investigate how long after birth the survivability of a triplet lamb was influenced by weight distribution within its litter and whether ewe age influenced weight variation within a triplet litter.

MATERIALS AND METHODS

Animals

Our project used lambing and post-mortem data collected from 1,672 ewes and their 5,016 triplet lambs. Data were collected from thirty seven commercial sheep flocks registered in the Sheep Improvement Ltd. (SIL) database, in the 2007 and 2008 lambing seasons (963 ewes in 2007, 709 ewes in 2008). The flocks were located in the Bay of Plenty (n = 1), Hawkes Bay (n = 3), Manawatu (n = 5), Canterbury (n = 2), Otago (n = 6) and Southland (n = 20) regions. Rising two-year-old ewes (n = 256) and mixed age ewes (n = 1,416) having three lambs to term without unusual circumstances involving being either premature, rotten, assistance or interference at birth, hand-reared, fostered, embryo transfer, congenital abnormalities, amnion over nose, or missing data were used for the study. There were 2,889 lambs in 2007 (1,437 ewes and 1,452 rams) and 2,127 lambs in 2008 (1,070 ewes and 1,057 rams) which met this criteria.

Collection and post-mortem of dead lambs

Lambs which died at birth and up to three days of age were collected, identified and recorded by the farmer during daily shepherding. The lambs were post-mortemed to determine cause of death using the lamb post-mortem protocol described by Everett-Hincks & Duncan (2008). Lambs were assigned a viability score (LVB) and either lamb death due to dystocia (LDD), starvation exposure (LDSE) or other causes such as abnormality, infection or unknown (LDOther).

Lambing data

Lambing data including lamb birth weight (kg), date of birth, parentage, sex and fate codes were recorded by farmers at least twice daily throughout lambing. Lambing data was entered onto the SIL database. The derived traits of total litter weight, average litter weight, birth rank, ewe age, lamb survival, and proportion of ram lambs in the litter (PRamLamb) were calculated from the lambing data. Lamb survival was recorded at birth (SurvB), at Day 3 after birth (Surv3d) and at weaning (SurvW). SurvB and Surv3d were determined by farmer observation and fate codes recorded in conjunction with the post-mortem results. SurvW was determined by the presence or absence of a lamb weaning weight.

To enable weight distribution to be compared between litter-mates the percentage of the total litter weight for each lamb was calculated (PLWT) by dividing the lamb birth weight by the total litter weight and multiplying by 100. The mean and standard deviation (SD) of the PLWT data from the 5,016 lambs were calculated and used to rank the birth weight of each lamb as Light (<Mean – 1 SD), Medium (Mean ± 1 SD), or Heavy (>Mean + 1 SD) within their litter compared to all lambs. This system of ranking meant that in litters which had comparatively little variation in birth weight within the litter, all the lambs were ranked as "medium" whereas other litters with more weight variation had any combination of "light", "medium" or "heavy" lambs, for example; Light, Light and Medium.

Average litter weight was calculated by dividing the sum of all lamb birth weights in the litter by the number of lambs (AveLBWT). The litter weight variation EwePLVar was calculated by subtracting the birth weight of the lightest lamb in litter from the birth weight of the heaviest lamb in the litter and dividing this by the total litter weight and recording as a proportion.

Ewe litter survival was calculated at each period after birth by dividing the surviving number of lambs with the number surviving at the previous period after birth. That is survival rate at birth (EweSRB) was calculated as the number of lambs alive at birth divided by the number of lambs born; survival rate at Day 3 (EweSR3d) was calculated as the number of lambs alive at Day 3 divided by the number of lambs alive at birth and survival rate at weaning (EweSRW) was calculated a the number of lambs alive at weaning divided by the number of lambs alive at Day3. Calculating the survivability in this manner meant that each time frame after birth could be assessed independently.

Statistical analyses

All the analyses were carried out in GenStat Version11 (VSN International Ltd., Hemel Hempstead, Hertfordshire, UK). PLWT, AveLBWT and EwePLVar were analyzed using a linear mixed model procedure.

The effects of ewe age group, sex and birth date on PLWT were assessed by fitting them as fixed effects. Sheep flock was fitted as a random effect to account for sheep flock differences. The effects of ewe age group, PRamLamb and birth year of litter on AveLBWT and EwePLVar were assessed and fitted as fixed effects.

The mortality and survivability of a triplet lamb, namely LVB, LDD, LDSE, LDOther, SurvB, Surv3d and SurvW, and the litter survival rates, namely EweSR1B, EweSR3d and EweSRW, were analyzed using the generalized linear mixed models procedure with logit link and the dispersion parameter fixed at 1. The mortality and survivability of a triplet lamb was modelled by fitting sex, ewe age group, PLWT rank, birth date and birth weight, with both a linear and quadratic term, as fixed effects and sheep flock as a random effect.

The litter survivability was modelled by fitting ewe age group, birth date of litter, EwePLVar, PRamLamb and AveLBWT, using only the linear term for EweSR3d and EweSRW and both the linear term and quadratic terms for EweSR1B, as fixed effects and sheep flock as a random effect.

All the possible two-way interactions for these models were tested but did not show significant effects; therefore the interactions were not included in the final models.

RESULTS

Lamb weight variation, survival and cause of death

The percentage of the total litter weight (PLWT) was significantly affected by the sex of the lamb ($P < 0.001$) (Table 1).

Lamb sex influenced survival (Table 1), viability at birth (LVB) and cause of death (Table 2) with ram lambs being less likely to survive at all stages after birth (all $P < 0.001$), less likely to be viable at birth ($P < 0.001$), and more likely to die of dystocia (LDD, $P < 0.001$) and "other" causes (LDOther, $P < 0.01$) than ewe lambs. Ewe age influenced lamb death with older ewes being generally less likely than rising two-year-old ewes to have lambs dying of dystocia ($P < 0.05$).

Lamb death by starvation exposure (LDSE) was not influenced by lamb sex or ewe age but was significantly affected by the day of birth (0.04 ± 0.010; log odds ratio /day, $P < 0.001$). Cause of lamb death by dystocia (LDD) and "other" causes (LDOther) were influenced by year of birth. The odds for LDD in 2008 were, on average, 0.402 (40%) less than the odds for LDD in 2007 (P <0.01) and the odds of LDOther in 2008 were on average, 0.290 (29%) less than the odds for LDOther in 2007 (P <0.01).

Analysis of the cause and time of death of dead lambs in association with weight within litter showed that weight rank was associated with all causes and times of death (Table 1 & 2).

The average rate of being viable at birth was 89.3% for Light lambs, 95.6% for Medium lambs and 98.0% for Heavy lambs (P <0.001). Lambs which were lighter than their litter mates had an 8.9% average rate of LDD, Medium lambs had 3.4% and Heavy lambs had 2.1% (P <0.001). The average rate of LDSE for Light lambs was 5.9%, for Medium lambs it was 3.7% and for Heavy lambs was 1.3% (P <0.01). Light lambs had a 13.8% average rate of LDOther, Medium lambs had 8.2% and Heavy lambs had 4.4% (P <0.001). There was a significant difference in the average rate of LDSE and LDOther deaths between medium lambs with large and small lambs however for LDD deaths the average rate was only significantly different between small and medium lambs (H.C. Mathias-Davis, Unpublished data).

TABLE 1: The effect of lamb sex, ewe age and weight rank within litter on lamb percentage weight proportion in litter (%) (Mean ± Standard error) and lamb survival to weaning (Proportion and Confidence interval). PLWT = Proportion litter weight of lamb (%); SurvB = Lamb survival at birth; Surv3d = Lamb survival at Day 3 after birth; SurvW = Lamb survival at weaning.

Item	Trait			
	PLWT	SurB	Surv3d	SurvW
Lamb sex				
Ewe	32.5 ± 0.1	0.927 (0.916, 0.938)	0.883 (0.869, 0.896)	0.820 (0.804, 0.834)
Ram	34.1 ± 0.1	0.874 (0.856, 0.890)	0.833 (0.815, 0.850)	0.761 (0.743, 0.779)
P value	<0.001	<0.001	<0.001	<0.001
Ewe age				
Two-year-old	33.3 ± 0.2	0.897 (0.879, 0.913)	0.851 (0.831, 0.870)	0.791 (0.770, 0.810)
Mature	33.3 ± 0.1	0.911 (0.898, 0.923)	0.868 (0.854, 0.881)	0.793 (0.778, 0.807)
P value	0.963	0.261	0.242	0.905
Size rank				
Light	-	0.802 (0.772, 0.828)	0.733 (0.703, 0.761)	0.644 (0.616, 0.672)
Medium	-	0.910 (0.896, 0.921)	0.863 (0.849, 0.877)	0.803 (0.789, 0.817)
Heavy	-	0.954 (0.942, 0.963)	0.931 (0.917, 0.942)	0.882 (0.864, 0.897)
P value		<0.001	<0.001	<0.001

TABLE 2: Effect of lamb sex, ewe age and weight rank within litter on lamb cause of death traits recorded between birth and three days of age (Proportion and Confidence interval). LVB = Lamb viability at birth; LDD = Lamb death risk from dystocia; LDSE = Lamb death risk from starvation exposure complex; LDOther = Lamb death risk from other causes.

Item	Trait			
	LVB	LDD	LDSE	LDOther
Lamb sex				
Ewe	0.966 ± (0.960, 0.971)	0.031 (0.026, 0.037)	0.030 (0.024, 0.038)	0.069 (0.059, 0.079)
Ram	0.938 ± (0.930, 0.946)	0.052 (0.044, 0.061)	0.031 (0.025, 0.039)	0.093 (0.081, 0.106)
P value	<0.001	<0.001	0.827	0.004
Ewe age				
Two-year-old	0.954 ± (0.945, 0.962)	0.049 (0.040, 0.061)	0.026 (0.020, 0.035)	0.091 (0.077, 0.107)
Mature	0.954 ± (0.948, 0.959)	0.033 (0.028, 0.038)	0.036 (0.029, 0.044)	0.070 (0.062, 0.080)
P value	0.963	0.023	0.172	0.053
Size rank				
Light	0.893 ± (0.875, 0.908)	0.089 (0.072, 0.108)	0.059 (0.048, 0.074)	0.138 (0.118, 0.160)
Medium	0.956 ± (0.951, 0.961)	0.034 (0.028, 0.040)	0.037 (0.030, 0.044)	0.082 (0.072, 0.093)
Heavy	0.980 ± (0.974, 0.985)	0.021 (0.016, 0.028)	0.013 (0.008, 0.021)	0.044 (0.035, 0.056)
P value	<0.001	<0.001	0.002	<0.001

TABLE 3: Effect of ewe age and proportion of ram lamb in her litter (PRamLamb) on ewe litter weight traits (Mean ± Standard error) and ewe litter survival rates between birth and weaning (Proportion and Confidence interval). EwePLVar = Variation in birth weight within litter (Proportion); AveLBWT = Average litter lamb birth weight (kg); EweSRB = Litter survival rate at birth; EweSR3d = Litter survival rate between Day 1 and Day 3 after birth; EweSRW = Litter survival rate between Day 3 and weaning.

Item	Trait				
	EwePLVar	AveLBWT	EweSRB	EweSR3d	EweSRW
Ewe age					
Two-year-old	0.106 ± 0.004	3.65 ± 0.07	0.876 (0.858, 0.893)	0.962 (0.952, 0.970)	0.946 (0.933, 0.956)
Mature	0.095 ± 0.002	4.17 ± 0.06	0.901 (0.890, 0.912)	0.967 (0.960, 0.972)	0.943 (0.934, 0.952)
P value	0.004	<0.001	0.055	0.485	0.791
PRamLamb					
No ram	0.099 ± 0.004	3.88 ± 0.07	0.902 (0.885, 0.917)	0.975 (0.967, 0.981)	0.953 (0.942, 0.963)
1/3 ram	0.104 ± 0.003	3.88 ± 0.06	0.909 (0.896, 0.920)	0.963 (0.954, 0.969)	0.942 (0.931, 0.952)
2/3 ram	0.100 ± 0.003	3.94 ± 0.06	0.882 (0.867, 0.896)	0.959 (0.950, 0.966)	0.941 (0.929, 0.951)
3/3 ram	0.099 ± 0.004	3.93 ± 0.07	0.859 (0.838, 0.878)	0.959 (0.949, 0.968)	0.940 (0.926, 0.952)
P value	0.529	0.166	0.004	0.255	0.636

TABLE 4: Effect of proportion of variation in birth weight within litter (EwePLVar) and average litter birth weight (AveLBWT) (kg) on litter survival rate at birth, between birth and three days and between three days after birth and weaning (Proportion and Confidence interval). EweSRB = Litter survival rate at birth; EweSR3d = Litter survival rate between Day 1 and Day 3 after birth; EweSRW = Litter survival rate between Day 3 and weaning.

Item	Litter survival rate		
	EweSRB	EweSR3d	EweSRW
EwePLVar			
0.00	0.926 (0.897, 0.947)	0.990 (0.983, 0.994)	0.975 (0.962, 0.983)
0.05	0.906 (0.871, 0.931)	0.988 (0.980, 0.992)	0.973 (0.960, 0.982)
0.10	0.881 (0.940, 0.913)	0.986 (0.977, 0.991)	0.972 (0.958, 0.981)
0.15	0.851 (0.801, 0.890)	0.983 (0.972, 0.990)	0.970 (0.956, 0.980)
0.20	0.815 (0.755, 0.863)	0.980 (0.967, 0.988)	0.969 (0.953, 0.979)
0.30	0.724 (0.641, 0.795)	0.973 (0.953, 0.984)	0.965 (0.947, 0.978)
0.40	0.610 (0.504, 0.707)	0.962 (0.933, 0.979)	0.962 (0.938, 0.976)
P value	<0.001	0.005	0.277
AveLBWT			
2	0.705 (0.592, 0.797)	0.967 (0.946, 0.980)	0.939 (0.909, 0.959)
3	0.835 (0.781, 0.878)	0.978 (0.964, 0.986)	0.957 (0.937, 0.971)
4	0.881 (0.840, 0.912)	0.985 (0.975, 0.990)	0.970 (0.956, 0.980)
5	0.881 (0.837, 0.914)	0.990 (0.983, 0.994)	0.979 (0.969, 0.986)
6	0.836 (0.761, 0.890)	0.993 (0.988, 0.996)	0.986 (0.977, 0.991)
7	0.706 (0.525, 0.839)	0.995 (0.991, 0.998)	0.990 (0.984, 0.994)
P value	0.012[1]	0.002	<0.001

[1]P value for quadratic term = 0.021

At birth, Light lambs had an 80.2% average survival rate, Medium lambs 91% and Heavy lambs 95.4% (P <0.001). By Day 3 after birth Light lambs had a 73.3% average survival rate, Medium lambs had 86.3% and Heavy lambs had 93.1% (P <0.001). At weaning the average survival rate for Light lambs was 64.4%, for Medium lambs 80.3% and for Heavy lambs 88.2% (P <0.001).

Ewe litter weight variation and survival

The proportion of variation in lamb weight within a litter (EwePLVar) was influenced by ewe age (P <0.01) where two-year-old ewes had more weight variation within their litters than older ewes (Table 3). Average litter weight was also affected by ewe age where older ewes had larger average litter weight than two–year-old ewes (AveLBW) (P <0.001). Litters with more ram lambs (PRamLamb) had a lower survival rate at birth (P <0.01) (Table 3). Litter survival rate at birth was highly significantly associated with EwePLVar (P <0.001), this effect was reduced but still significant at Day 3 after birth (P <0.01) but no longer significant for survival to weaning (Table 4). In contrast, AveLBWT was more strongly associated with litter survival as the time from birth increased (EweSRB, P <0.05; EweSR3d, P <0.01; EweSRW, P<0.001).

DISCUSSION

This study had a number of objectives. The first was to confirm the earlier finding by Morel *et al.* (2008) that the mortality of a triplet lamb is influenced by the birth weight of its littermates, that is the weight distribution within the litter, rather than the birth weight of the lamb itself. This study supports Morel *et al.* (2008) and found that the mortality of a lamb at birth, after three days and up to weaning was significantly associated with weight rank independently of birth weight and that the survival rate of a litter at birth was significantly affected by the proportion of variation in lamb weight within a litter and not by the average litter weight. Morel *et al.* (2008) used the percentage of total litter weight for each lamb which related to mortality and also found that the coefficient of variation in litter birth weights was lower for tripleting ewes weaning all three lambs than for those tripleting ewes weaning only one or two lambs.

The second aim of this study was to determine what time period after birth the weight variation within triplet litters influences lamb survival. The method of calculating litter survival in this study assessed each period after birth independently which enabled the time when mortality was most influenced by litter weight distribution to be identified. Survivability analyses demonstrated that the effect of weight variation within litter was most pronounced at birth and reduced after this with average litter weight becoming more important for litter survival with increased time from birth. This may be explained by the increased likelihood of the lighter lambs within a litter being able to descend into the birth canal alongside one of the other lambs, contributing to the higher incidence of difficult and prolonged birth in triplets (Everett-Hincks *et al.*, 2007) and possible death from dystocia in both affected lambs. It could be assumed that lambs which die from a primary cause of dystocia are more likely to die shortly after birth compared to a lamb which dies from a primary cause of starvation and exposure. Lamb death from starvation exposure has been associated with low birth weight (Everett-Hincks & Dodds, 2008); this may explain the increased association of survivability and average litter weight as time after birth increases. Analysis of lamb time of death in association with cause of death would give more insight into this. The study showed that weight variation was associated with cause of death, with Light lambs being more likely to die from all causes than Medium and Heavy lambs. The increased risk of death by starvation exposure is explained by their lower birth weight and the increased risk of death by dystocia for the reasons outlined earlier. This study also showed that the likelihood of death by dystocia was not significantly different for Medium and Heavy lambs within a triplet litter which confirms previous findings (Kerslake *et al.*, 2005; Everett-Hincks & Dodds, 2008).

The study's final objective was to investigate the influence of ewe age on weight variation within a litter. The results showed that two-year-old ewes were more likely to have greater weight variation within their litter than litters born to older ewes. Two-year-old ewes also had more lambs dying from dystocia. The relationship between death by dystocia and weight rank was significant and so the increased weight variation within litters of younger ewes may also explain the increased lamb death by dystocia.

In summary, we have shown that weight variation in a triplet litter affects lamb survival, especially at day one after birth. This effect is most significant for lambs born to two-year-old ewes. More investigation into the causes of increased weight variation within litter and development of farming practices to minimise this would decrease triplet mortality. Our study shows that specifically targeting methods to reduce litter weight variation in two-year-old ewes having triplets would be particularly valuable.

ACKNOWLEDGEMENTS

Financial assistance was provided by Ovita Ltd. The authors are extremely grateful to all of the farmers involved in the study, the Invermay lamb survival team and Sheep Improvement Limited (SIL). The authors also thank Dr. Ken Dodds.

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