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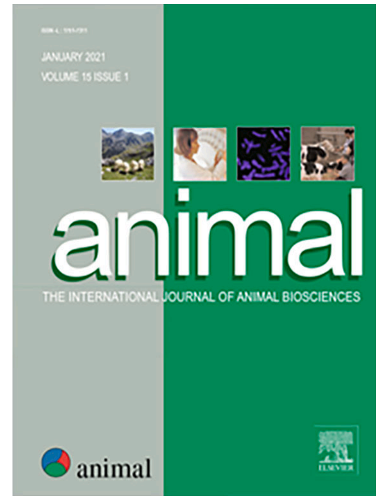

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Genetic Analysis of a Maternal Assistance Score in Sheep

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Highlights

- A easy to measure maternal assistance score for sheep was assessed.
- The simple score is heritable and repeatable.
- The score was negatively genetically correlated with the number of lambs reared.
- This score could be used as a selection criterion to improve rearing percentage.
- This score could lead to an improvement of lamb welfare by reducing mortality.

Abstract

Maternal behaviour is important for lamb survival, as ewes perform many behaviours that affect the chances of a lamb surviving. Collecting maternal behaviour data directly at lambing is time consuming and not considered suitable for acquiring the large volumes of data that would be required for using as selection criteria within commercial breeding flocks. The aim of this study was to investigate if a simple scoring system is heritable and assesses expression of behaviours that reduce the probability of lamb mortality. Ewe behaviour was scored on a 3-point Maternal Assistance Score **(MAS)**: (1) the ewe shows a high level of maternal interest (assumed if no intervention required); (2) the ewe shows limited interest in her lamb; and (3) the ewe shows no interest in her lamb. A total of 19 453 MAS were collected over 12 years, across 24 farms (including both indoor and outdoor lambing systems) and 12 different breed lines that make up the Innovis breeding programme. Ewe parity, breed, number of lambs carried, flock, lambing batch, lambing day within flock and pre-mating weight all had a significant effect on MAS ($P<0.05$). The maternal assistance score was shown to be heritable ($h^2=0.05$) and repeatable (0.10), positively genetically correlated to lambing difficulty (rg=0.29) and amount of assistance the lamb required to suckle from the ewe (rg=0.88), and negatively genetically correlated with the number of lambs successfully reared (rg=0.49). This study shows that an easy to measure score can be used by shepherds with large breeding flocks, based on whether the ewe requires further assistance to support her lamb rearing. The score could be used in breeding programmes to select for lamb rearing ability in the future and potentially lead to an improvement in lamb welfare through a reduction in mortality.

Keywords: Genetic parameters, Heritability, Lamb survival, Scoring system, Maternal behaviour

Implications

Maternal behaviour has an important role in lamb survival and early lamb growth. A simple maternal assistance score in sheep was assessed to evaluate if it was heritable, repeatable and related to lamb survival and early lamb growth. This study indicates that the maternal assistance score could be easily measured in commercial breeding flocks and could be used as a selection criterion to improve the number of lambs reared by a ewe.

Introduction

Improving lamb survival is an important aim for the sheep sector, as lamb losses have a welfare and financial cost to the industry and are a major contributor to sheep reproductive inefficiency. It is estimated between 10-15% of lambs die before weaning every year in the UK and around the world (Dwyer et al., 2016). Improving maternal behaviour and strengthening the ewe-lamb bond has been shown to have a positive impact on the welfare of ewes and lambs (Muhammad et al., 2022). There are also societal pressures to reduce lamb mortality and to increase welfare across the industry with consumers expressing preferences for products from higher welfare systems (Eurobarometer, 2015).

Previous studies have shown that lamb survival is influenced by many factors, including sex of lamb, breed, birth weight, litter size born, length and difficulty of birth and the behaviour of the ewe and lamb (Dwyer & Lawrence, 2005). Selection for lamb survival has been shown to be possible but has a low heritability (0.01; Brien et al., 2010; 0.18; Sawalha et al, 2007). Alternative approaches have been focused on selection for related traits which may influence survival, such as lambing difficulty score (h^2= 0.2; Macfarlane et al., 2010) and a lamb suckling assistance score (h^2 = 0.32; Macfarlane et al., 2010; Matheson et al., 2012). Time taken for the lamb to bleat, rectal temperature and crown-rump length have been shown to have a genetic correlation with lamb survival to weaning (h^2 =0.11, 0.10 and 0.30 respectively; Brien et al., 2010). However, these measures are time consuming to record at lambing time, may only be feasible in indoor managed ewes and may not be easily recorded in large breeding flocks.

Early post-natal ewe behaviour is important to create an exclusive olfactory bond between the ewe and her newborn lambs: this ensures that the ewe restricts her maternal care only to her own lamb which increases the chance of her lamb surviving (Dwyer & Lawrence, 2005). The ewe should perform specific behaviours that help her lamb survive, including selecting an adequate birth site, remaining on that site until the lambs can follow her, licking and grooming the lamb, performing low pitched bleats, standing still to allow the lamb to suckle and not showing aggressive or rejecting behaviours, such as butting the lamb away (Dwyer & Lawrence, 1999;2005). These behaviours improve olfactory bonding by the ewe and assist the lamb to find the udder and suck quickly. With scores already developed for measuring lambing difficulty and lamb suckling behaviour, selecting for maternal behaviours that ensure a good bond is formed could be an additional way to improve lamb survival in flocks.

Maternal behaviour in ewes can be affected by many factors, including age, parity, breed, environment, and nutritional status. For example, multiparous ewes have been shown to have better maternal behaviour than primiparous ewes (Dwyer & Lawrence, 1998). Primiparous ewes are more likely to take longer to start grooming their lambs, be more fearful of the lamb and more likely to show aggression towards the lamb (Dwyer, 2008). These outcomes lead to a poorer ewe-lamb bond and together with lower birth weights lead to poorer survival for the lambs. There have been many studies investigating the differences between breeds in maternal behaviour. For example, Suffolk ewes (a typical UK lowland breed), when compared to Scottish Blackface ewes (a typical UK hill breed), were slower to start grooming their lambs after birth, and overall spent less time grooming compared to the Scottish Blackface ewes. They were also more likely to show fearful and aggressive behaviours towards the lamb (Dwyer & Lawrence, 1998). Merino ewes have been shown to spend less time on the birth site and have higher levels of desertion compared to other New Zealand breeds (reviewed by Dwyer, 2008). Differences between breeds in maternal behaviour indicate that these behaviour traits may be heritable and that there may be the possibility of genetic selection for these traits.

Creating a measuring system that can be used to record all the phenotypes that indicate good maternal behaviour, to enable genetic selection, is complex. Individually recording these phenotypes is time consuming and impractical in an extensive commercial system. Current methods used within published research are labour intensive at lambing time, which is already a busy time of year, when there is limited time to follow detailed protocols to record the information needed to select for ewes that have good maternal behaviour. The Maternal Behaviour Score outlined by

O'Connor et al. (1985), has been developed to be a quick and easy method of measuring maternal care. The Maternal Behaviour Score measures how far away the ewe moves from her lambs, when the lambs are handled by the shepherd within 24 hours of birth, typically for ear tagging. The 5-point score ranges from the ewe keeping close to her lamb (score 5) to running away and not coming back once the lamb is released (score 1). This score has been used in many studies with varying results. Some studies found improved lamb survival and weaning weights were associated with higher Maternal Behaviour Scores (O'Connor et al., 1985). However, Lambe et al (2001) only found a difference in survival to weaning between the lowest maternal behaviour category and other scores. Other studies did not find a link between Maternal Behaviour Score and lamb survival (at birth or to weaning) or lamb weights at weaning (Everett-Hincks & Cullen, 2009). This score is a measure of the balance between two conflicting behaviours: the attraction of the ewe for her lambs (a measure of the strength of her maternal relationship to the lambs); and her fear of the human handler or her reactivity. Thus, this score may be influenced by how often the ewe is handled and previous human interactions.

An alternative measuring system which is practical to record in a commercial environment is proposed in this study as a simple 3-point score. Preliminary results from these analyses were presented in Hay et al (2022). The present study further considers the factors affecting the new score of maternal behaviour, based on whether assistance is needed by the ewe and her lambs, when recorded in large commercial flocks, lambing indoors or outdoors, and assesses whether this score is heritable, repeatable, and linked to lamb survival and early lamb growth. The purpose of the study is to assess if this score is under genetic control that would allow selection against the ewes with poorest lamb rearing ability in a breeding programme to improve the maternal behaviour of the flock and improve lamb welfare through the reduction of lamb mortality.

Material and methods

Animal and Management

Data was collected over 12 years (between 2008 and 2021), across 24 different farms, spread throughout the UK (indoor lambing (n=19) and outdoor lambing (n=4)), and over 7 different breeds that make up the Innovis breeding programme. The breeds assessed were split into maternal and terminal breeds. Maternal breeds (using a selection index including number of lambs born and maternal ability) were: Aberfield (n= 8986), Highlander (n= 789), North Country Cheviot (n= 213), Abertex (n=5413) and Lleyn (n= 1096) and terminal breeds (selection index focused on growth rates and carcase composition) were: Abermax (n= 1691) and Primera (n= 669).

Score Collection

A novel, simple maternal assistance score **(MAS)** was used where ewe maternal behaviour was assessed on a 3-point score, at the ewe level (one score per litter), where 1: the ewe shows a high level of maternal interest, 2: the ewe shows limited interest in her lamb(s) and 3: the ewe shows no interest in her own lamb(s) or rejects her own lamb(s). For example, ewes that were head butting and kicking the lamb were scored a 3, whereas ewes that were initially not letting the lamb suck or were not licking the lamb were scored a 2. The scores were manually assessed by shepherds (across 24 flocks), there was little crossover between shepherds and farms and no formal training was given to shepherds before they collected the data. The scores were assigned within 24 hours of the ewe giving birth. In an indoor system the scores were collected in the individual pens that the ewe and her lambs were moved into after birth, based on general observations. In an outdoor system the scores were only recorded if there was an observed problem and the ewe and her lamb(s) had to be moved into a small indoor pen. All other outdoor lambing ewes were assumed a score of 1 (the ewe shows a high level of maternal interest) because there was no intervention with the ewe and her lamb(s) in the post-natal period.

Data

A total of 21 934 records were collected for MAS, with 52% of the ewes in the dataset recorded for more than one lambing event, varying from 2 records to 7. For 48% of ewes in the dataset only one lambing event was recorded, this is due to a combination of these being young flocks and management decisions to cull poor performing ewes. Ewes were recorded for a range of other traits, including pre-mating weights and condition score (on a scale of 0-5, recorded in increments of 0.5, Russel et al., 1969); number of lambs scanned (at pregnancy scanning, 10 weeks prior to the start of lambing), number of lambs born and reared to 48 hours. When the ewe gave birth, scores were assigned for: lambing difficulty (on a scale of 1-5 measured at birth, where 1= the lamb didn't require any assistance, 2= the lamb was assisted but would have lambed on its own, 3= the lamb needed assistance, 4 = the lamb needed substantial assistance, 5= veterinary assistance was required; Macfarlane et al., 2010; Matheson et al., 2012); lamb survival (up to 48 hours, 0 = did not survive, 1 = survived); birth weight; and a lamb suckling assistance score (which was a variation of the lamb suckling score described by Macfarlane et al., 2010, where 1= the lamb needed no help suckling, 2 = the lamb required help with the initial feed, 3= the lamb required artificial feeding up to 24 hours old, 4= the lamb required artificial feeding after 24 hours old). The lambs were then recorded for 8-week live weight (actual age varied between 42 and 84 days, average 66 days) and scan live weight (between 45 and 245 days, average 125 days), when lambs were ultrasound scanned for muscle and fat depth, over the 3rd lumbar vertebra. At ultrasound scanning, three individual subcutaneous fat depth measurements were taken over the *longissimus lumborum* muscle, from which the average fat depth was calculated **(UFD)** and a single muscle depth was taken at the deepest point of the muscle **(UMD)**. Any flock that was assigned MAS = 1 for more than 99% of animals in a year was removed from the dataset due to potential recording errors in the flock. This resulted in data for one year in one flock being removed from the dataset (n=1 463). Ewes that reared another ewe's lamb (fostered, n = 1 018) were also removed from the dataset, since the maternal behaviour of ewes that reared a lamb that was not their own was considered to potentially be a separate trait to her behaviour towards her own lambs. After removing these records, 19 453 MAS records on 10 528 ewes remained for analysis.

Statistical Analysis

Factors affecting MAS were assessed using multiple linear regression in GenStat (VSN International, 2022). MAS was considered as a continuous variable for the analysis. All available biologically sensible explanatory factors or covariates and their two-way interactions were tested in the model to explain variation in MAS. Fixed effects tested were year of lambing (12 levels, 2008-2020), batch of lambing (an individual batch number for every lambing batch on each farm every year e.g. early lambing, main lambing, ewe lamb lambing; 176 levels), ewe year of birth (19 levels, 2000-2019), parity of the ewe (7 levels, 1-7), litter size the ewe was born into (4 levels, 1-4), lamb breed (14 levels), ewe pre-mating weight (covariate), ewe pre-mating condition score (covariate), number of lambs at pregnancy scanning (4 levels, 1-4), and lambing day within flock (the day the ewe lambed after the first lambing that happened in that batch, covariate). Model terms were included in the final model if they had a significant effect on MAS ($P<0.05$).

Phenotypic associations were assessed between MAS of the dam and several important lamb traits: birth weight, lamb survival, lambing difficulty, lamb suckling assistance score, live weight of the lamb at eight weeks old **(8WW)**, live weights of the lamb at ultrasound scanning (scan weights), UFD, UMD. In these analyses, a model was derived for each lamb trait using stepwise regression considering the following fixed effects, where relevant (Table 1): flock (24 levels), batch (209 levels), year of birth of the lamb (14 levels), parity of the dam (7 levels), breed of the lamb (14 levels), breed of the ewe that reared the lamb (7 levels), age of the lamb at the time of measurement (8WW or ultrasound scan), management group (the group that the lamb was weighed in; at 8WW or ultrasound scan), scan weight (for ultrasound tissue depths), sex (3 levels), birth type (litter size, 5 levels), birth weight, UFD and UMD of the lamb. Two different models for lambing difficulty score were fitted – either including or excluding birth weight (as a covariate). MAS was then included in the final explanatory model for each lamb trait, fitted as a factor with 3 levels (score 1, 2 or 3). Predicted means for MAS were calculated for each lamb trait and pair-wise t-tests assessed if differences between MAS scores were statistically significant.

For the genetic analysis of MAS, variance components for MAS were estimated using univariate analysis with an animal model in ASReml (Gilmour et al., 2021). The associated pedigree file included 121 858 pedigree records over 21 generations. A similar model was fitted for MAS as described above for the phenotypic analysis. The final model used for MAS in the genetic analyses was:

$$\begin{aligned} y = \ & Flock + Lambing\ Batch + Parity + Ewe\ Breed + Pre\ Tupping\ Weight + Lambing\ Day \\ & + No\ Scanned + Flock\ x\ Parity + Flock\ x\ No\ Scanned \\ & + Pre\ Tupping\ Weight\ x\ Ewe\ Breed + Animal + \ AnimalPE + e \end{aligned}$$

Where, flock x parity = the interaction between flock and the parity of the ewe; flock x no scanned = the interaction between flock and the number of lambs the ewe was scanned as carrying; pre-mating weight x ewe breed = the interaction between the ewe's weight pre-mating and the number of lambs the ewe was scanned as carrying;

Animal = random ewe direct additive genetic effect; AnimalPE = random ewe permanent environmental effect associated with multiple lambing records of the same dam, and e = random residual effect.

Similarly, genetic analyses were performed for other key traits associated with the ewe (pre-mating live weight and body condition score, number of lambs scanned, born and reared) and her lambs (lambing difficulty, suckling, survival, live weights, UMD and UFD), using univariate models in ASReml. Models were created for the other traits of interest with the significant explanatory factors show in Tables 1 and 2, which were fitted along with any significant 2-way interactions between model terms. The random effects included in the models for each of the ewe traits were the direct genetic effect of the animal and the permanent environmental effect of the animal, except for the model for the number of lambs scanned, where the permanent environmental effect of the ewe was not significant so not included. In the lamb trait models, the random effects were the direct genetic effect of the lamb, the permanent environmental effect of the dam and the genetic effect of the dam, except for lamb suckling assistance score where the genetic effect of the dam was not significant so was not included in the model.

Direct heritability for each trait included in the genetic analyses was calculated as the ratio of the direct additive genetic variance to the observed total phenotypic variance. Repeatability (for the ewe traits) was calculated as the ratio of genetic variance plus permanent environmental effect of the ewe to the total phenotypic variance. Maternal heritability (for the lamb traits) was calculated as the ratio of the maternal genetic variance to the observed total phenotypic variance. To assess genetic relationships of MAS with other ewe and lamb traits, bivariate analyses were performed in ASReml between MAS and each trait of interest, using the same pedigree file and the genetic models outlined above. Phenotypic correlation between MAS and the other ewe traits were calculated from the variance component outputs of the genetic analysis. Genetic correlations were estimated using bivariate analyses in ASReml.

Results

Descriptive statistics for maternal assistance score and the other ewe and lamb traits

Initial analysis of the raw data of the MAS shows that 94.5% of records had a MAS of 1 (the ewe shows a high level of maternal interest); only 4% of records were scored as 2; and 1.5% of records were scored a 3 (the ewe shows no interest in the lamb or rejects her own lamb). Table 3 shows a summary of the ewe and lamb traits of interest. There was an average loss of 0.1 lambs between scanning and birth, and 0.2 lambs from birth to weaning, and an overall lamb mortality to 48 hours of 11%.

Factors affecting maternal assistance score

There was a significant effect of ewe parity on MAS ($P<0.05$): mean MAS for 3rd and 4th parity ewes (1.01 and 1.02, respectively) were significantly lower/better ($p<0.05$)

than for 1st and 2nd parity ewes, which had the highest/ poorest mean MAS (1.06 and 1.04, respectively). Ewes of parity 5 or 6+ did not differ significantly in MAS (means 1.02 and 1.01, respectively) from any other parities except parity 1 ewes (1.06). Number of lambs scanned also affected MAS, with ewes scanned for singles having significantly lower (better) mean MAS (1.02, $P<0.05$) than ewes scanned with twins, which had significantly lower MAS (1.03, $p<0.05$) than ewes scanned with triplets (mean MAS 1.06). There were too few quadruplet-bearing ewes measured to be fully included in the model so these ewes were removed from the analysis. There were significant differences in mean MAS between breeds ($P<0.05$), with the maternal breeds generally having a better mean MAS than the terminal breeds. Flock, batch of lambing, lambing day within flock and pre-mating weight (an increase in body weight decreased the average MAS) all had a significant effect on MAS ($p<0.05$). The other factors and covariates tested in the models to explain variation in MAS (year of lambing, ewe year of birth, ewe pre-mating condition score) had no significant effect, suggesting that they do not affect MAS in these flocks.

Phenotypic effects of maternal assistance score on lamb traits

Birth weights of lambs from ewes with MAS of 2 were significantly lower than those from ewes assigned a MAS of 1 or 3 ($P<0.05$, Table 4). For lambing difficulty (without birth weight in the model), lambs from a ewe with a MAS 2 had the highest predicted mean birth difficulty score (most difficult births), with lambs from a ewe with a MAS of 1 having the lowest predicted mean for lambing difficulty (easiest births; Table 4) and lambs from ewes with MAS 3 intermediate, all MAS scores significantly differ from each other for lambing difficulty ($P<0.05$). When birth weight was included in the model, there was a significant difference between MAS 1 (lower score) compared to scores 2 and 3 for lambing difficulty (Table 4). Similarly, MAS 1 was associated with lambs with the lowest predicted mean suckling assistance scores (least assistance required), compared to significantly higher suckling assistance scores for lambs of ewes given MAS 2 or 3 ($P<0.05$). For UFD, as with birth weight, there was a significant difference in predicted means between MAS 1 compared to MAS 2, and MAS 2 compared to MAS 3, but not when MAS 1 was compared to MAS 3, with MAS 2 associated with the lowest birth weights and highest UFD. MAS was not a significant effect ($P>0.05$) in models for lamb survival, 8WW, scan weight and UMD. There was a trend for ewes scoring 1 and 2 for MAS to have lambs that were more likely to survive than lambs from a ewe scoring MAS 3, however, these differences fell below statistical significance ($P=0.14$).

Genetic analysis of maternal assistance score and other key ewe and lamb traits

Significant explanatory factors for the ewe traits are shown in Table 2. Flock and ewe breed were significant for all the traits of interest, and parity was significant for all except pre-mating condition score. Significant explanatory factors for the lamb traits are shown in Table 1. Although sex of the lamb was the only factor that was significant for all the lamb traits of interest, parity, breed and birth type were significant for all but one trait. The heritability estimates for MAS and number of lambs scanned, born and reared, were low (all 0.11 or less, Table 5). Moderate heritabilities were estimated for ewe pre-mating weight and condition score (Table 5). The heritability of ultrasound measured traits in the lambs (UMD and UFD) were also moderate in magnitude (Table 6) and higher than the lamb growth traits (birth weight, 8-week weight and scan weight, respectively 0.13,0.15 and 0.13). The trait of birth difficulty was also more heritable than the growth traits (0.21, Table 6). Lamb suckling assistance score and lamb survival had low heritability. MAS had a low but significant repeatability across parities (0.10, Table 5), pre-mating ewe weight and condition score had higher repeatabilities across parties (0.66 and 0.26 respectively), whereas number of lambs born and reared had lower repeatabilities of 0.11 and 0.06, respectively (Table 5). Maternal heritability (Table 6) was highest for the early lamb growth traits (e.g., birth weight and 8-week weight; 0.09 and 0.08) and lowest for ultrasound muscle depth (0.01).

Relationships of maternal assistance score with other recorded traits of the ewe and lamb

Genetic and phenotypic correlations between MAS and traits of the ewe were generally low (-0.16 – 0.16), with the exception of the genetic correlation with number of lambs reared, which was moderate and negative (Table 7). Correlations with pre-mating weight and pre-mating condition score were negative and significant (Table 7), indicating that an increase in pre-mating weight or condition score was associated with a lower MAS (better maternal behaviour). There was a significant positive genetic and phenotypic correlation between number of lambs scanned and MAS indicating that ewes carrying a larger litter size were genetically and phenotypically more likely to get poorer (higher) MAS after giving birth. There was a moderate negative genetic correlation between number of lambs reared to 48 hours and MAS, meaning that ewes with a genetic propensity to require more assistance at birth reared fewer lambs.

There were significant positive genetic correlations between MAS and lambing difficulty (either with or without adjustment for birth weight), indicating that difficulty lambing is associated with ewes needing more assistance (Table 7). There was a very high, significant positive genetic correlation between lamb suckling assistance score and MAS. Although a positive genetic correlation was estimated with MAS for lamb survival, a relatively large standard error meant that it was not significantly different from zero. There were low, but significant, genetic correlations between growth traits (8-week weight, scan weight) and MAS, where a better MAS was associated with higher growth rates. Genetic correlations with ultrasound measured tissue depths were not significantly different from zero.

Discussion

This study demonstrates that the MAS, as defined in this study, is lowly heritable (0.05) and repeatable over a ewe's lifetime (0.10). Selection for this trait could have favourable effects on other commercially important traits, like lambing difficulty, early lamb behaviour (ability of the lamb to suckle unaided) and number of lambs successfully reared. The score assessed the amount of assistance that was given to a ewe based on her interest in her lamb(s). It is important to recognise, however, that this is likely to be a composite measure composed of the maternal behaviour and maternal abilities of the ewe, the ease of delivery of her lamb(s) and the vigour and activity of her lambs.

Phenotypic effects on maternal assistance score and effects of maternal assistance score on lamb traits

Primiparous ewes had the highest mean MAS, indicating they were most likely to require assistance, with the amount of assistance required to ensure a strong maternal-offspring bond decreasing as the ewe gives birth to her second and subsequent litters. It has previously been shown that primiparous ewes are reproductively less efficient, have immature physiological and hormonal responses to birth leading to impacts on the onset of maternal behaviour and are more likely to show aggression to their lambs than multiparous ewes (Dwyer & Lawrence, 2005). Their offspring are also more likely to require assistance to suck successfully from the ewe; confirmed in this study. Breed was a significant factor explaining variation in MAS, indicating different breeds represented in this study required different levels of assistance. The maternal breeds that have been selected to breed replacement ewes for the flock had a lower MAS than the terminal breeds, primarily selected for siring slaughter lambs based on growth and carcase traits. This is similar to previous studies with a variety of different breeds that have shown breed differences in maternal behaviour, e.g. Dwyer & Lawrence (1998) showed a difference between the maternal behaviour of Suffolk ewes and Scottish Blackface ewes and Merino ewes have been shown to have a higher desertion rate when compared to other New Zealand breeds (reviewed by Dwyer, 2008). On average, ewes that were scanned with a larger litter size had a higher MAS, indicating that they are more likely to need additional assistance. Relationships between litter size, maternal care and lamb survival have been shown in many studies. For example, twin born lambs receive less grooming than single born lambs, which may affect the strength of the ewe-lamb relationships, (Dwyer & Lawrence, 1998). It has also been shown that multiple born lambs are slower to reach behavioural milestones (e.g. time taken lambs to stand, seek and suck the udder) than single or twin born lambs, independent of the differences in birth weight (Dwyer, 2003). Many studies have shown that survival for triplet born lambs is much lower than for twin or single born lambs (Kenyon et al, 2019). This could indicate that triplet lambs need more care and are more likely to need assistance from a shepherd, so the ewe is more likely to receive a poorer maternal assistance score. Pre-mating weight had a significant effect on MAS, as pre-mating weight increased MAS decreased, indicating that heavier ewes at mating were less likely to require assistance. This is likely to be linked to the ewe’s ability to maintain condition and produce lambs heavier at birth, which are less likely to require assistance (reviewed by Dwyer et al, 2016).

There were significant differences in many of the lamb traits measured at birth between lambs from ewes awarded MAS 1 and MAS 2 (birth weight, lambing difficulty, suckling assistance score) but generally not in the traits measured after that (survival, growth, carcass composition) except for fat depth at ultrasound scanning at around 18 weeks old. There were not always differences in lamb traits between MAS 1 and 3, and MAS 2 and 3. This could be related to the intervention that was likely to happen when a ewe was scored 3. For the ewe to be assigned the poorest score (3) the shepherd would likely have intervened, for example, removing the lamb from the ewe, helping the lamb by providing supplementary feeding or assisting it with feeding from the ewe. However, ewes that were given a MAS of 2 might not have required as much intervention, which reduces overall time spent with the animal and level of additional support given to the lamb and the ewe that could influence post-natal and subsequent performance of the lamb.

Genetic analysis of maternal assistance score and other key ewe and lamb traits

In this study, the estimated heritability for maternal assistance score was 0.05, which is slightly lower than published estimates from studies using the O'Connor et al (1985) score, which were between 0.09 and 0.20 (Brien et al., 2010; Everett-Hincks et al., 2005; Everett-Hincks & Cullen, 2009; Lambe et al., 2001). This could be because the MAS used in this study was a more subjective score than the O'Connor maternal behaviour score, with little guidance given to shepherds to standardise the scores. There was likely to be more environmental variance in this study due to many recorders and limited training given to the people recording. This is likely to have increased the variation in scores awarded between different shepherds, therefore inflated the overall phenotypic variance and diluted the effect of the genetic variance, reducing the heritability. Ideally it would be preferable to determine the repeatability of scoring within and between observers, to quantify the effect of recorder on MAS. This increased variance may also happen due to manmade data recording errors. There may be potential for either AI or CCTV to be used in future smaller-scale studies, to minimize the error in manual trait recording. However, these technologies would not be feasible in many of the areas in which ewes lambed in the current study.

Within the genetic parameters estimated for MAS, the repeatability, calculated as the ration of genetic variance plus permanent environmental effect of the ewe to the total phenotypic variance, of the maternal assistance score was estimated at 0.10. This is in the lower end of the range of published estimates of repeatability for the O'Connor Maternal Behaviour Score, with estimates ranging from 0.09 to 0.32 (Everett-Hincks et al., 2005; Lambe et al., 2001). Heritabilities for lamb weight and carcase traits are similar to previously published studies (Macfarlane et al., 2010; Safari et al., 2005). Lamb survival heritability was low but significant (0.02), which is similar to previously published estimates (Everett-Hincks et al., 2014; Sawalha et al., 2007), suggesting that, although lamb survival is heritable, selecting for this trait alone will achieve only slow improvements in lamb survival over generations. Selecting for other or additional traits that have an effect on lamb survival could speed up this process. The heritability for lamb suckling assistance score was 0.06 in this study, which was lower than other published estimates ranging between 0.10 and 0.34 (Cloete et al., 2002; Macfarlane et al., 2010). This could be due to a higher proportion of lambs in this study assigned a score of 1 (no assistance required): the average score in this study was 1.1 and the average score in the study by Macfarlane et al. (2010) was 1.4. The heritability for lambing difficulty score was 0.21 which is in the upper end of the range of published estimates for this trait (0.01 to 0.21; Brown, 2007; Macfarlane et al., 2010). Heritabilities for ewe pre-mating weight and condition score (Conington et al., 2001; McLaren et al., 2022) and for the ewe reproductive traits (number pregnancy scanned, number born and number reared) were in line with previously published estimates (Bunter et al., 2016; Hanford et al., 2002; Lambe et al., 2008).

Relationships of maternal assistance score with other recorded traits of the ewe and lamb

Low, but significant, genetic correlations between ewe body condition score or live weight at mating with MAS, suggest that ewes that were lighter or had a lower body condition score before mating were genetically more likely to have a higher MAS, which could be linked to the ewes ability to maintain condition and produce heavier lambs at birth (Gardner et al, 2007) which are less likely to need assistance (reviewed by Dwyer et al, 2016). Ewes with a larger litter scanned also had a higher MAS, and it has been shown that lambs from larger litters take longer to bond with the ewe (Chniter et al, 2017). There was a significant negative genetic correlation between MAS and number of lambs the ewe reared, indicating that ewes with genetic propensity for needing more assistance rear fewer lambs, equating to higher lamb mortality. Lamb survival has also been shown to decrease when ewes were scored as having poorer maternal care using the O'Connor et al. (1985) Maternal Behaviour Score (Everett-Hincks et al., 2005). This was attributed to an increase in lambs dying of exposure and dystocia in outdoor lambing systems (Everett-Hincks & Dodds, 2008). These data together demonstrate that maternal care plays an important role in lamb survival and developing robust methods to allow this to be scored in the field can contribute to a strategy for genetic improvement in lamb survival.

There was a very strong genetic correlation between lamb suckling assistance score and MAS, indicating a genetic relationship between the amount of assistance the lamb needs to suckle and maternal behaviour as scored by MAS. Previous studies have shown that suckling plays an important role in the development of recognition of the ewe by the lamb (Goursaud & Nowak, 1999), and when lambs are slower to suckle it takes more time for the ewe to recognise the lamb. MAS may also include an element of lamb behaviour because it is identifying ewes whose lambs need extra care. There was also a moderate positive genetic correlation between MAS and lamb difficulty score in the current study, where a higher (worse) lambing difficulty score was correlated with a higher (worse) MAS. It has been shown that ewes that experience a difficult birth show a lower expression of maternal behaviour (Dwyer & Lawrence, 1998; Redfearn et al., 2023). Likewise, studies have found that greater birth difficulty causes impaired lamb behaviour development (Dwyer, 2003; Matheson et al., 2012). As these lambs often need more care, ewes would be likely to score higher on the MAS as the shepherd might need to intervene with these lambs. There were low but significant negative correlations between MAS and 8-week weight or scan weight, indicating less interest in lambs around birth (higher MAS) is associated with lighter lambs both at 8 weeks and 16 weeks. This is consistent with other published estimated using the O'Connor maternal behaviour score with a worse score being associated with lighter lambs at weaning (O'Connor et al, 1985). The results from this study imply that MAS score could be used in recording protocols within breeding programmes to select for ewes requiring less assistance at birth. This score could be incorporated in maternal selection indices to decrease the number of ewes requiring assistance at birth in the flock and could have a positive effect on lamb survival, lambing difficulty, lamb suckling and early lamb growth.

In conclusion, this study shows that an easy to measure score (MAS), which can be used by shepherds on large commercial farms (indoor or outdoor lambing), based on whether the ewe requires further assistance to support her maternal care and lamb rearing, is heritable (h^2=0.05). Despite the low heritability, this is greater than the heritability estimates typically reported for lamb survival alone (Brien et al., 2010), which suggests that this could be a valuable addition to selection indices. This score is easy to use in commercial farming systems, including outdoor lambing, and it is possible that, with some development or greater precision relating to conditions under which the scores are assigned, the heritability could increase by reducing the environmental variance. However, even with no training or guidance, the score is heritable and the simplicity of the score and lack of detailed guidance may contribute to improved uptake and use. The score also has favourable effects on other commercially important traits, like lambing difficulty, whether the lamb needs assistance at suckling and number of lambs successfully reared. The score could be used in breeding programmes by incorporation into maternal indexes to select for ewes with better scores that would require less assistance at birth which would increase lamb survival and welfare. Future work is required to develop optimised maternal selection indices including these traits.

Ethics approval

The data analysed for this study were collected on a number of commercial breeding flocks for the primary purpose of participating in a commercial breeding programme. These data were retrospectively used for the secondary purpose of research. Therefore, no prior approval was required by an Animal Ethics Committee.

Data and model availability statement

None of the data were deposited in an official repository. The data that supports the study findings belong to a commercial company and are not publicly available.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors did not use any artificial intelligence assisted technologies in the writing process.

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Declaration of interest

The authors declare that they have no conflict of interest.

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Table 1

Factors affecting lamb traits and therefore included in the model for the trait, p<0.05.

Trait	Explanatory Factors													
	Flock	Lambing Batch	Year of Birth	Parity	Breed	Rear dam breed	Age at 8-week weights [1]	8-week management	Age at ultrasound scan[1]	Ultrasound scan management	Scan weight	Sex	Birth Type	Birth weight
Birth weight	*	*		*	*	*						*	*	n/a
Lambing difficulty (with birth weight)		*		*	*							*	*	*
Lambing difficulty (without birth weight)		*		*	*							*	*	
Lamb suckling score	*	*		*	*							*		*

Lamb survival	*	*		*	*							*	*	*
8-week weight				*	*	*	*	*				*	*	
Scan weight	*	*	*	*	*	*			*	*		*	*	
UMD	*		*							*	*	*	*	
UFD	*	*	*	*	*	*				*	*	*	*	

UMD = ultrasound muscle depth, UFD = ultrasound fat depth, n/a = not applicable therefore not tested.

[1] Age at 8-week weights and age at ultrasound scan measured in days.

Table 2

Factors affecting ewe traits and therefore included in the model for the trait, p<0.05.

	Explanatory Factors							
Trait	Flock	Lambing Batch	Year of Birth	Parity	Ewe Breed	Ewe Birth Type	Pre-mating weight	Pre-mating condition score
Pre-mating condition score	*	*			*			n/a
Pre-mating weight	*	*		*	*	*	n/a	
Number of lambs scanned	*			*	*		*	*
Number of lambs born	*			*	*		*	
Number of lambs reared	*			*	*		*	

n/a denotes where the explanatory factors were not tested in that model.

Table 3

Mean, SD, minimum (min) and maximin (max) for maternal assistance score, ewe traits and lamb traits.

Trait	N	Mean	SD	Min	Max
Maternal assistance score (1-3)	19395	1.1	0.31	1	3
Pre-mating condition score (1-5)	13856	3.4	0.63	1	5
Pre-mating weight (kg)	15381	65.9	11.31	29.3	109.0
Number of lambs scanned	13744	1.8	0.62	1	4
Number of lambs born	14756	1.7	0.65	1	4
Number of lambs reared	14685	1.5	0.63	1	3
Birth weight (kg)	38491	4.5	1.09	0.5	10.5
Lambing difficulty score (1-5)	37935	1.3	0.74	1	5
Lamb suckling score (1-5)	35112	1.1	0.39	1	4
Lamb survival (0-1)	38364	0.89	0.32	0	1
8-week weight (kg)	28440	23.4	5.37	8	40
Scan weight (kg)	33956	34.3	6.58	14.0	54.8
UMD (mm)	33977	22.5	4.10	10.2	34.8
UFD (mm)	33992	1.8	0.81	0.3	9.8

UMD = ultrasound muscle depth, UFD = ultrasound fat depth.

Table 4

Phenotypic least squares means for each lamb trait due to maternal assistance score.

Maternal Assistance Score	1	2	3	σ^2	*p-value*
Birth weight	4.2[a]	4.0b[b]	4.3[a]	1.2	*<0.001*
Lambing difficulty (with birth weight)	1.75[b]	1.88[a]	1.85[a]	0.54	*<0.001*
Lambing difficulty (without birth weight)	1.48[c]	1.69[a]	1.60[b]	0.54	*<0.001*
Lamb suckling assistance score	1.14[b]	1.29[a]	1.27[a]	0.15	*<0.001*
Lamb survival	0.558[a]	0.561[a]	0.533[a]	0.07	*0.140*
8-week weight	23.6[a]	23.7[a]	23.5[a]	29.5	*0.845*
Scan weight	30.6[a]	30.4[a]	29.9[a]	43.9	*0.242*
UFD	2.24[b]	2.32[a]	2.16[b]	0.67	*0.012*
UMD	21.9[a]	21.9[a]	21.6[a]	16.2	*0.385*

UFD = ultrasound fat depth, UMD = ultrasound muscle depth.

Within row, means sharing a common superscript are not significantly different from each other.

σ^2 denotes statistical variance.

Table 5

Variance components from ASReml for ewe traits (± SE).

Trait	V_a	V_p	Heritability	Repeatability
Maternal assistance score	0.004±0.001	0.087±0.001	0.05±0.01	0.10±0.01
Pre-mating weight	13.93±1.12	42.92±0.69	0.39 ± 0.02	0.66 ± 0.01
Pre-mating condition score	0.04±0.00	0.26±0.00	0.22 ± 0.02	0.26 ± 0.01
Number of lambs scanned	0.04±0.00	0.21±0.00	0.11 ± 0.01	n/a
Number of lambs born	0.03±0.01	0.37±0.00	0.09 ± 0.01	0.11 ± 0.01
Number of lambs reared	0.02±0.00	0.36±0.00	0.05 ± 0.01	0.06 ± 0.01

V_a indicates the additive variance and V_p indicates the phenotypic variance.

n/a is where the repeatability could not be estimated.

Table 6

Variance components from ASReml for ewe traits (± SE).

Trait	V_a	V_p	h^2	h^2_m
Birth weight	0.08±0.01	0.67±0.01	0.13 ± 0.01	0.09±0.01
Lambing difficulty score (with birth weight)	0.09±0.01	0.46±0.00	0.21 ± 0.01	0.06±0.01
Lambing difficulty score (without birth weight)	0.10±0.01	0.40±0.00	0.21±0.01	0.06±0.01
Lamb sucking assistance score	0.01±0.00	0.14±0.00	0.04 ± 0.01	n/a
Lamb survival	0.08±0.06	4.29±0.08	0.02 ± 0.01	0.03±0.02
8-week weight	2.34±0.24	15.40±0.19	0.15 ± 0.01	0.08±0.01
Scan weight	2.77±0.33	21.51±0.21	0.13 ± 0.01	0.06±0.01
UMD	0.10±0.03	4.10±0.04	0.32 ± 0.02	0.06±0.01
UFD	0.002±0.000	0.010±0.000	0.23 ± 0.02	0.01±0.01

V_a indicates the additive variance and V_p indicates the phenotypic variance, h^2 indicates heritability and h^2_m indicates maternal heritability.

UMD = ultrasound muscle depth, UFD = ultrasound fat depth

n/a is where the maternal heritability could not be estimated.

Table 7

Results from bivariate analysis for maternal assistance score and other ewe traits (± SE).

Trait	Genetic Correlation	Phenotypic Correlation
Pre-mating condition score	-0.16 ± 0.08	-0.04 ± 0.01
Pre-mating condition score with weight	-0.12 ± 0.07	-0.04 ± 0.01
Pre-mating weight	-0.16 ± 0.06	-0.04 ± 0.01
Pre-mating weight with condition score	-0.16 ± 0.06	-0.03 ± 0.01
Number of lambs scanned	0.16 ± 0.11	0.03 ± 0.01
Number of lambs born	-0.01 ± 0.12	0.05 ± 0.01
Number of lambs reared	-0.49 ± 0.12	-0.10 ± 0.01
Birth weight	-0.16 ± 0.11	
Lamb difficulty score with birth weight	0.29 ± 0.13	
Lamb difficulty score without birth weight	0.20 ± 0.13	
Lamb suckling assistance score	0.88 ± 0.07	

Lamb survival	0.17 ± 0.18
8-week weight	-0.10 ± 0.01
Scan weight	-0.20 ± 0.12
UMD	-0.02 ± 0.08
UFD	-0.04 ± 0.09

UMD = ultrasound muscle depth, UFD = ultrasound fat depth.