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Ruminants

Effects of Breeding for Short-Tailedness in Sheep on Parameters of Reproduction and Lamb Development

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ABSTRACT

Background: Sheep's tail docking is a widespread practice, which is banned or critically discussed in some countries to improve animal welfare.

Objective: The aim was to determine the influence of breeding for short-tailedness (ST) or long-tailedness (LT) in sheep on the development of reproduction parameters and lamb performance.

Method: One hundred forty-nine ewes were mated with four rams according to tail length. Pregnancy and pregnancy loss rates were calculated. During pregnancy, the progesterone levels (P4) of the ewes were measured. The weight and length of the 254 lambs were recorded up to 14 weeks of life. Litter size, placenta weight, sex, stillbirths, vitality, morbidity and mortality of the lambs were also documented.

Results: No significant differences were found for P4 and placental weight for the two mating groups (ST and LT). Although the pregnancy rate for ST was slightly lower (75.71%) than for LT (87.34%), there was only a low significant difference ($p = 0.07$). The sex distribution was 61 (48.80%) male and 64 (51.20%) female lambs in the ST group and 67 (51.94%) male and 62 (48.06%) female lambs in the LT group. The twinning rate was not significantly different (ST 75.20%; LT 75.97%), and no significant difference was found in the average body length and vitality of the lambs. However, LT lambs showed better weight gains that were marginally significant ($p = 0.09$).

Conclusion: This study found no evidence that reproductive parameters or lamb performance were affected by selective breeding based on tail length.

1 | Introduction

Because long, woolly tails lead to increased accumulation of faeces and dirt in the perianal area (especially in cases of diarrhoea due to nutrition or disease), amputation of the caudal spine is common practice in the husbandry of long-tailed (LT) sheep breeds (Shelton 1977). A tail shortened by docking is intended to counteract excessive faecal soiling and, consequently, the development of sores and infections in the tail and anogenital region (Shelton 1977; Sutherland and Tucker 2011). The primary objective is to prevent the nesting of fly larvae and resulting wound myiasis (Wall 2012), which may have fatal consequences for animals if left untreated. Furthermore, sheep with longer tails have been demonstrated to be more prone to fractures of the caudal spine (Hümmelchen, Wagner, et al. 2023).

Various studies indicate that amputation of the caudal spine causes pain and pain-associated behavioural changes in lambs (Grant 2004; Pollard, Roos, and Littlejohn 2001). Conversely, it has been shown that long, undocked tails are at increased risk of injury (Hümmelchen, Wagner, et al. 2023). Therefore, breeding for short tails (ST) is an alternative to amputation; it preserves the advantages of a shorter tail while preventing the pain associated with the procedure (Hümmelchen et al. 2022). For these reasons, potential negative consequences associated with breeding for short-tailedness (such as deformities associated with the shortening of the tail) must be investigated. The effects may involve the area of the anus and rectum or may be associated with more distant regions of the body, such as caudo-rectal genitourinary syndrome and anophthalmia-anuria syndrome in cattle (Wiesner and Willer 1974). A classic example of a negative trait associated with short-tailedness involves the Manx cat. Due to a significant shortening of the caudal spine in these cats, anatomical changes of the pelvic structures occur, which are often associated with urinary and faecal incontinence as well as restricted mobility of the hind limbs (DeForest and Basrur 1979; Robinson 1993). Deformities associated with tail length have also been observed in dogs (Hytönen et al. 2009; Indrebø et al. 2008). These malformations are attributed to a mutation in the T-gene, which appears to be primarily responsible for the expression of tail length (Buckingham et al. 2013). A recent study demonstrates a potential influence of the *HOXB6*, *HOXB8* and *HOXB13* genes on tail length, with the *HOXB13* gene thought to exert the greatest effect (Lagler et al. 2022).

There have been various studies on the heritability of tail length in sheep; in addition, a so-called 'NoTail' breed was created in the course of one study. However, this breed exhibited a lethal factor, 'sidewheeler', which was characterised by compression of the spinal cord nerves in the tail area, leading to increasing paralysis of the hindquarters during the rearing phase of lambs (Wilson 1940; Jordan 1952).

The aim of this study was to investigate the effect of selective breeding of LT and ST breeding pairs on the course of pregnancy as well as vitality and development of lambs until weaning.

2 | Materials and Methods

2.1 | Ewes

To assess the effects of breeding on short-tailedness, selective breeding of a Merino sheep population was carried out by dividing the sheep into two groups. Specific data for group allocation can be found in Oberpenning et al. (2022). At the time of the experiment, the breeding pairs were located at the Oberer Hardthof teaching and research farm of the Justus-Liebig University in Giessen. One hundred forty-nine ewes were divided into either an ST ($n = 70$) or LT ($n = 79$) group. Rams ($n = 4$) were also divided into ST (Rams 1 and 2) and LT (Rams 3 and 4) groups according to tail length. Breeding was conducted according to tail length, such that LT ewes were mated with an LT ram and ST ewes with an ST ram (Table 1). After in-hand breeding in August and September 2021, ewes were examined on the 35th and 70th days of gestation. The following data were collected: progesterone concentration in blood in ng/mL, pregnancy status, pregnancy rate and pregnancy losses. After birth, 40 placentae were weighed.

Pregnancy examination on the 35th and 70th days of gestation was performed transabdominally on the right side in the wool-free inguinal region with the Honda HS-1600 ultrasound scanner (Honda Electronics Co. Ltd., Toyohashi, Aichi, Tokyo, Japan) using a convex probe (HCS-736M) and a frequency of 7.5 MHz. An ultrasound gel (CV-Sonic, C+V Pharma-Depot GmbH, Versmold, Germany) was used for all ultrasonographic examinations.

Progesterone concentration was determined from blood samples using the mini Vidas device (bioMérieux, Marcy I'Etoile, France), which works according to the ELFA test principle (enzyme-linked fluorescent assay).

The placentae ($n = 40$) were cleaned and weighed using a digital table scale (Kerbl, Albert Kerbl GmbH, Buchbach, Germany). Only complete placentae that were found immediately after birth were weighed.

The pregnancy rate is defined as the number of ewes that did not show oestrus symptoms again after the first pairing. Animals that showed renewed oestrus symptoms after mating were paired with the same ram a second time. The number of pregnancy losses includes the number of ewes who, after a positive pregnancy examination on the 35th day of gestation, were no longer pregnant at the repeated pregnancy examination on the 70th day of gestation or at the expected date of birth.

2.2 | Lambs

Of 254 lambs born between 17 January 2022 and 23 February 2022 at the Oberer Hardthof teaching and research farm of the Justus-Liebig University in Giessen, the first examination of the parameters described below was carried out on the second day of life at the latest: body weight (kg), body length (cm), sex and litter size. Within the first 48 h after birth, the vitality of the lambs was documented. Body weight and length were recorded weekly until 6 weeks of age, then again at 10 and 14 weeks.

The body weight of the lambs was determined up to a weight of 15 kg using a digital table scale (Kerbl, Albert Kerbl GmbH, Buchbach, Germany) and thereafter using a digital sheep scale (Patura KG, Laudenbach, Germany). Body length was measured in centimetres using a roll-up measuring tape, which was attached to a homemade device and could be extended cranially. The lambs' hindquarters were held against a wooden bar to which the tape measure was attached, and the tape measure was extended to the transition from the neck to the back area. More detailed information about the measuring method can be found in Hümmelchen, Wenisch, et al. (2023).

A lamb was classified as vital if it showed undisturbed behaviour, normal condition and regular milk consumption. A lamb was classified as sub-vital if it did not drink independently in the first 48 h after birth or showed signs of illness, such as weakness,

TABLE 1 | Mating distribution presented as absolute frequencies and percentages of the two groups: Short-tailed (ST) and long-tailed (LT). Mean (M) and standard deviation (SD) of ewe tail length are shown in brackets.

	Ram 1, ST	Ram 2, ST	Ram 3, LT	Ram 4, LT	Total
Ewe, ST (M: 21.69 cm, SD: 1.65 cm)	33 22.15%	37 24.83%	0 0.00%	0 0.00%	70 46.98%
Ewe, LT (M: 24.98 cm, SD: 1.93 cm)	0 0.00%	0 0.00%	40 26.85%	39 26.17%	79 53.02%
Total	33 22.15%	37 24.83%	40 26.85%	39 26.17%	149 100.00%

diarrhoea, increased body temperature or respiratory distress. A daily visual inspection of the lambs was carried out by a vet. From these observations, morbidity and mortality were defined as binary (0/1) coded traits for the first week of life and for the entire observation period (up to 14 weeks).

2.3 | Statistics

Various statistical models were used to investigate the effects of selective breeding on the different pregnancy parameters as well as lamb development.

The effect of selective breeding and other fixed effects on linear traits for ewes (progesterone concentrations, placenta weight) and lambs (body weight and body length at birth and in Week 14, daily body weight and body length gain) were calculated using linear mixed models.

Binary traits (stillbirth, mortality within the first week of life, mortality from the second week of life, morbidity over the entire study period and sub-vitality) were corrected for the two breeding groups and other influencing factors using a generalised linear model. The procedure GLIMMIX of the statistical program SAS OnDemand for Academics (SAS 2023) was used for this purpose. For binary traits, the LSmeans for the respective probabilities of occurrence were transformed using a logit link function.

Ewe traits were analysed using the following models:

$$y_{ijklm} = \mu + \text{litter size}_i + \text{selective breedin g}_j + \text{parity}_k + \text{day of gestation}_l + \text{ewe}_m + e_{ijklm}$$

>where y_{ijklm} is the observations for progesterone concentrations (P4-Model 1)

$$y_{ijklm} = \mu + \text{litter size}_i + \text{parity}_k + \text{selective breeding}_j \times \text{day of gestation}_l + \text{ewe}_m + e_{ijklm}$$

where y_{ijklm} is the observations for progesterone concentrations (P4-Model 2)

$$y_{ijk} = \mu + \text{litter size}_i + \text{selective breeding}_j + \text{parity}_k + e_{ijk}$$

where y_{ijk} is the observations for placenta weight and μ is the overall mean effect; litter size$_i$ is the fixed effect of ith litter size (i = single, twin, triplet); selective breeding$_j$ is the fixed effect of jth selective breeding group (j = short-tailed ram + short-tailed ewe, long-tailed ram + long-tailed ewe); parity$_k$ is the fixed effect of kth parity (k = 1, 2, 3, > 3); day of gestation$_l$ is the fixed effect of lth pregnancy stage (l = 35th day of pregnancy, 70th day of pregnancy); ewe$_m$ is the random effect of mth ewe (m = 1–149); e_{ijklm} is the random residual effect.

For the fertility traits pregnancy rate and pregnancy loss rate, a chi-square test was carried out to compare the two matings.

Lamb traits were analysed using the following models:

$$y_{ijkl} = \mu + \text{litter size}_i \times \text{selective breeding}_j + \text{parity}_k + \text{sex}_l + e_{ijkl}$$

where y_{ijkl} = observations for body weight and body length at birth and in week 14

$$y_{ijklmn} = \mu + \text{litter size}_i + \text{selective breeding}_j + \text{parity}_k + \text{sex}_l + \text{age}_m + \text{lamb}_n + e_{ijklmn}$$

where y_{ijklmn} is the observations for daily body weight and body length gain

$$\text{logit}(\pi) = \log\left[\pi_{ijklmn} / \left(1 - \pi_{ijklmn}\right)\right] = \mu + \text{litter size}_i + \text{selective breeding}_j + \text{parity}_k + \text{sex}_l$$

where π_{ijklm} is the probability of occurrence for stillbirth, mortality within first week of age, mortality within 2nd–14th week of age, morbidity for the whole period, sub-vitality within 48 h p.p. and μ is the overall mean effect; litter size$_i$ is fixed effect of ith litter size (i = single, twin, triplet; for body weight and length only two categories single and multiple); selective breeding$_j$ is fixed effect of jth selective breeding group (j = short-tailed ram + short-tailed ewe, long-tailed ram + long-tailed ewe); *parity*$_k$ is fixed effect of kth parity (k = 1, 2, 3, > 3); sex$_l$ is fixed effect of lth sex (l = female, male); age$_m$ is fixed effect of mth age (1st–6th week of age, 10th + 14th week of age); lamb$_n$ is random effect of nth lamb (n = 1–254).

3 | Results

3.1 | Ewes

The frequency of mating between ST and LT breeding pairs is shown in Table 1.

The pregnancy rate after the first mating was 75.71% (n = 53) for the ST group and 87.34% (n = 69) for the LT group. A total of 27 animals (18.12%) showed oestrus symptoms after the first mating. The pregnancy loss rate of the ST group (5.71%; n = 4) was slightly higher than that of the LT (3.80%; n = 3). The pregnancy rate shows only a small, significant difference (p = 0.07), while

TABLE 2 | *p*-values from the global F-test of the fixed effects on progesterone (P4-Model 1) and placenta weight. P4-Model 2 shows the results of the model with the interaction “gestation day*selective breeding”.

Effect	P4-Model 1	P4-Model 2	Placenta weight
Day of gestation	0.04	—	—
Parity	0.08	0.08	0.02
Litter size	< 0.0001	< 0.0001	0.15
Selective breeding	0.38	—	0.24
Selective breeding* day of gestation	—	0.18	—

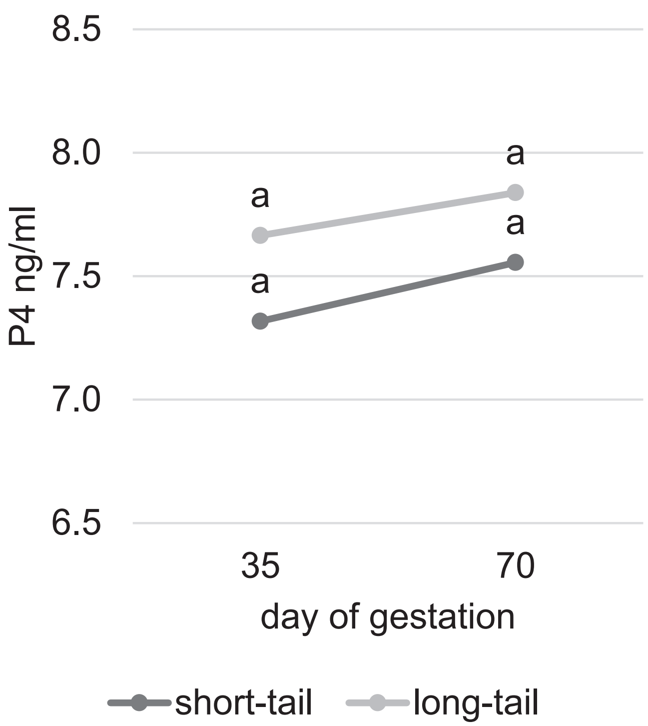

FIGURE 1 | LSmeans of progesterone concentration (P4) on Day 35 and Day 70 of gestation in the two groups (short-tailed, long-tailed). The interaction of gestation day and breeding group is not significant ($p < 0.05$) for the gestation day, as well as in the pregnancy progression.

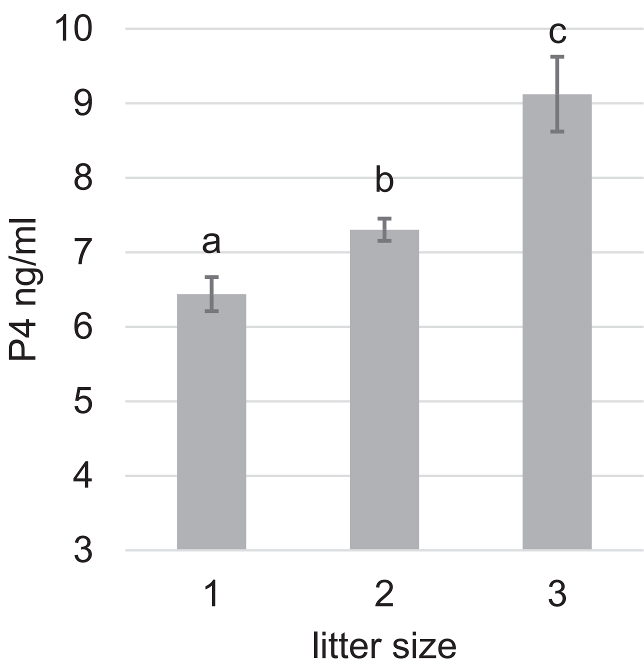

FIGURE 2 | LSmeans of progesterone concentration (P4) for different litter sizes. Significant differences ($p < 0.05$) are marked with different letters.

the pregnancy loss rate does not differ significantly between the two mating groups ($p = 0.58$). The gestation period of 150.07 ± 1.00 days in the ST group did not differ from the gestation period of 149.80 ± 1.23 days in the LT group.

The influence of various factors on progesterone concentration (P4) during pregnancy is shown in Table 2.

Selective breeding or the number of previous lambings did not influence P4. The interaction of selective breeding and gestation length was also not significant ($p = 0.18$). Nevertheless, LT ewes demonstrated a higher P4 value than ST on both gestation days (Figure 1).

The LSmeans of P4 across groups was 7.44 ± 0.20 ng/mL on the 35th day and 7.75 ± 0.20 ng/mL on the 70th day of gestation. The difference between the two-time points was significant. For pregnant ewes from the ST group, the P4 value on the 35th day was 7.32 ± 0.25 ng/mL, while that from the LT group was 7.56 ± 0.24 ng/mL. On the 70th day of gestation, mean P4 in the ST group was 7.39 ± 0.25 ng/mL and in the LT group was 7.84 ± 0.24 ng/mL (Figure 1).

Significant differences in the P4 value were found for litter size. Accordingly, triplets with a P4 of 9.05 ± 0.49 ng/mL demonstrated the highest concentration (singletons: 6.45 ± 0.22 ng/mL, twins: 7.28 ± 0.15 ng/mL) (Figure 2).

As shown in Table 2, the number of previous lambings significantly influenced the placenta weight. A significant effect on placenta weight was not found for litter size or selective breeding. The LSmeans for placenta weight were 0.55 kg for the ST group and 0.44 kg for the LT group.

3.2 | Lambs

ST breeding produced 61 male (48.80%) and 64 female (51.20%) lambs. These comprised 13 singletons (10.40%), 94 lambs from a

TABLE 3 | *p*-values from the global F-test of the fixed effects on body length (BL) and body weight (BW) at birth and at the 14th week of life (LW), number of stillbirths, mortality probability within the 1st LW and from the 2nd LW, he morbidity probability over the entire experimental period as well as daily body length development (BLD) and body weight development (BWD) over the entire experimental period.

	Influencing factors					
Features	**Parity**	**Litter size**	**Sex**	**Selective breeding**	**Age**	**Litter size *selective breeding**
BL Birth	0.009	—	0.0581	—	—	< 0.0001
BL_14th LW	0.47	—	< 0.0001	—	—	0.0009
BW_Birth	0.0002	—	0.0024	—	—	< 0.0001
BW_14th LW	0.0109	—	< 0.0001	—	—	< 0.0001
BLD	0.34	0.82	0.49	0.91	< 0.0001	—
BWD	0.02	< 0.0001	0.0003	0.09	< 0.0001	—
Stillbirths	0.33	0.35	0.01	0.27	—	—
Mortality probability ≤ 1st LW	0.85	0.39	0.60	1.00	—	—
Mortality probability > 1st LW	0.98	0.98	0.89	0.11	—	—
Susceptibility to disease	0.77	0.98	0.89	0.98	—	—
Sub-vitality	0.28	0.0008	0.58	0.87	—	—

TABLE 4 | Probability of stillbirths, probability of mortality within the first week of life (LW) and from the second LW onwards, as well as probability of disease over the entire experimental period for short-tailed (ST) and long-tailed (LT) selective breeding.

	ST	**LT**
Stillbirths	2.30%[a]	4.52%[a]
Mortality probability ≤ 1. LW	0.24%[a]	0.24%[a]
Mortality probability > 1. LW	0.09%[a]	0.02%[a]
Probability of disease	0.22%[a]	0.00%[a]

twin pregnancy (75.20%) and 18 lambs from a triplet pregnancy (14.40%). There were 67 male (51.94%) and 62 female (48.06%) lambs in the LT group. Of these lambs, 25 were singletons (19.38%), 98 lambs were from a twin pregnancy (75.97%) and 6 lambs (4.65 %) were born as triplets.

A total of 14 lambs were stillborn; nine lambs died within the first week of life and six other lambs died later. Eight lambs required veterinary treatment during the study period. The diseases included diarrhoea ($n = 5$), which was attributed to coccidia based on the result of a faecal sample examination. In addition, umbilical inflammation ($n = 1$), pneumonia ($n = 1$) and arthritis ($n = 1$) were documented.

The probability of stillbirth, mortality or susceptibility to disease in relation to selective breeding, as determined by the threshold model, is shown in Table 3. While the probability of stillbirth was 4.52% for the LT group, a probability of only 2.36% was determined for the ST group (Table 4). In contrast, ST lambs had a higher probability of mortality from the second week of life (0.09%) than LT lambs (0.02%). The probability of disease for the entire study period was 0.22% for ST lambs and 0.00% for LT lambs. Nevertheless, none of these parameters shows a significant difference between the two groups.

As shown in Table 3, the average growth rate of body length was not significantly related to litter size, sex, selective breeding, age of the lambs or number of previous lambings of the ewes. In contrast, the average weight development of the lambs demonstrated a significant influence by litter size, sex, number of previous lambings of the ewes and age of the lambs. Selective breeding showed a marginally significant influence on daily weight gain.

Sex of the lambs significantly affected the probability of stillbirth ($p = 0.01$), as 8.20% of male lambs were stillborn versus 1.26% of female lambs. All other fixed effects tested, such as number of previous lambs and litter size, had no significant effect on the number of stillbirths and susceptibility to increased mortality and morbidity. Although the raw data showed a clustered occurrence of disease cases in lambs from short-tail selective breeding, no significant effect was found for selective breeding in the model. Since the model corrects for clustering in certain effect levels, the difference between LSmeans was not significant.

The probability that a lamb was sub-vital showed no significant difference in terms of sex, number of previous lambings or selective breeding (Table 3). There was a significant relationship between sub-vitality and litter size ($p = 0.0008$). The probability of a lamb from triplets being sub-vital was highest, at 1.49% (singleton: 0.00 %; twin: 0.93%).

Apart from a significantly different probability of stillbirths, sex was not significantly associated with any other parameter. This also applies to litter size, for which a significant effect was found only for the probability of sub-viability.

LSmeans of birth weight of singleton lambs in the ST group was 6.59 ± 0.22 kg; for the combined group of multiple lambs

TABLE 5 | LSmeans for body length (BL, in cm) and body weight (BW, in kg) of lambs from the short-tailed (ST) and long-tailed (LT) pairings, separated into singletons and multiples.

	BW		BL	
	Birth	**14th LW**	**Birth**	**14th LW**
Singleton, ST	6.59[a] (0.22)	47.23[a] (1.65)	34.82[a] (0.61)	64.78[ab] (1.16)
Multiple, ST	5.10[b] (0.08)	41.62[c] (0.60)	31.90[b] (0.23)	62.73[b] (0.42)
Singleton, LT	6.43[a] (0.16)	49.56[a] (1.15)	34.64[a] (0.45)	66.40[a] (0.81)
Multiple, LT	5.24[b] (0.08)	43.33[b] (0.57)	32.46[b] (0.22)	63.41[b] (0.40)

Significant differences ($p < 0.05$) are marked with different letters. Standard errors are shown in brackets.

(≥ 2 lambs), this was 5.10 ± 0.08 kg. The average birth weight of singletons in the LT group was 6.43 ± 0.16 kg, and that for multiples was 5.24 ± 0.08 kg. At the last measurement in the 14th week of life, ST singletons had an average body weight of 47.23 ± 1.65 kg; for multiples, the value is 41.62 ± 0.60 kg. LT singletons had an average weight of 49.56 ± 1.15 kg, and multiples were 43.33 ± 0.57 kg at this time. The LSmeans for the body weights of the different groups of lambs are shown in Table 5. At 14 weeks, LT multiple lambs reached significantly higher average weights than ST lambs. For the measurement at birth and at 14 weeks, significant differences in litter size could be found, independent of group.

LSmeans of daily weight gain over the entire study period were 0.41 ± 0.02 kg per day for ST singletons and 0.36 ± 0.01 kg for ST multiples. LT singletons gained an average of 0.44 ± 0.01 kg per day, and LT multiples gained 0.37 ± 0.01 kg.

The LSmeans for the body length of singletons in the ST group was 34.82 ± 0.61 cm at birth. Multiples (≥ 2 lambs) in the ST group had a significantly different body length of 31.90 ± 0.23 cm at birth. The body length of singleton lambs in the LT group was 36.64 ± 0.45 cm; the average body length of multiple lambs in the LT group was 32.46 ± 0.22 cm. At the last measurement in the 14th week of life, ST singletons had an average body length of 64.78 ± 1.16 cm and multiples were 62.73 ± 0.42 cm. At this time, LT singletons showed an average body length of 66.40 ± 0.81 cm and LT multiples were 63.41 ± 0.40 cm. LSmeans for the body lengths of the different groups are shown in Table 5. These results demonstrate that singleton lambs were significantly larger than multiple lambs at the time of birth and at 14 weeks. Even though the LT lambs predominantly had higher average body lengths, only a slightly significant difference could be found for singletons compared to ST lambs (Table 5).

The LSmeans for the growth rate of body length over the whole study period was 0.37 ± 0.29 cm per day for the ST group and 0.38 ± 0.30 cm per day for the LT group.

4 | Discussion

In the context of implementing a breeding value for targeted breeding for short-tailedness in sheep, it is necessary to investigate possible negative effects on reproductive performance and lamb rearing of short-tailed ewes.

The aim of this study was to determine whether there are differences in reproductive parameters and the lamb performance for the two groups (ST and LT).

A slightly higher pregnancy rate was found for LT ewes (87.34%) compared to short-tailed ewes (75.71%). The difference was only marginally significant ($p = 0.007$). Both pairings had a physiological gestation period for sheep of 150 ± 2 days (Bostedt, Ganter, and Hiepe 2019).

In addition, progesterone was measured as a further parameter of the endocrine function of the placenta during pregnancy (Bostedt, Ganter, and Hiepe 2019). It was found that selective breeding did not cause significant differences in P4. Only time of measurement during pregnancy and litter size were significantly associated with progesterone levels. Previous studies have also demonstrated that progesterone level increases significantly with the number of foetuses and the duration of gestation (Pasciu et al. 2022; Boscos et al. 2003; Gür et al. 2011). This is explained by the fact that there is more placental tissue that synthesises P4 in a multiple pregnancy than in a singleton pregnancy (Pasciu et al. 2022; Karen et al. 2001) and that the placenta replaces the ovaries as the source of progesterone synthesis in sheep during progressive pregnancy (Silver 1994). Both groups of ewes were within the physiological lambing rate of 150%–200% for Merino sheep (Bellof and Granz 2018).

The lack of significant differences in reproduction parameters suggests that the fertility of ewes is not influenced by selective breeding (ST and LT).

A comparison of the lambs from the two groups showed that selective breeding had no significant influence on body length development and only a marginally significant influence on body weight development. The interaction of selective breeding and litter size was significant for body length and body weight at birth and at 14 weeks of age. Thus, a higher average body weight at 14 weeks was recorded for lambs of LT breeding pairs. However, this led to statistically significant differences only in the case of multiples. This leads to the assumption that naturally LT animals may demonstrate better weight gain. Whether this development continues with further shortening of the tail in the next generations in the course of breeding selection must be further investigated.

A previous genetic study about the relationship between tail length and body weight (Lagler et al. 2022) indicated that lambs with longer tails have more favourable genes for positive weight development. This advantage is relativised by the fact that a long tail can lead to a higher susceptibility to disease, for example, increasing the risk of infection in the event of diarrhoea and the risk of fractures (Hümmelchen, Wagner, et al. 2023; Oberpenning et al. 2022). It is not expected that selection for shorter tails will have a significant impact on body weight development, as there are only minor adverse effects on weight (Oberpenning et al. 2022).

As expected, this study found that male lambs had both a significantly higher body weight and a significantly greater body length than females at birth and at 14 weeks. A higher birth weight of male lambs compared to females has been established in other studies (Von Senden genannt Havercamp, Brandt, and Erhardt 2015; Bohte-Wilhelmus et al. 2010). Larger body weight and body length in singletons compared to multiples have also been described elsewhere (Washaya, Ngorio, and Mudzengi 2023; Eck et al. 2019).

The statistical analysis of parameters of lamb performance, such as the stillbirths and the susceptibility to lamb losses, did not reveal any significant influences by selective breeding in the model calculation. This is of great importance, especially with regard to a successful rearing rate, which is essential for sheep farmers. A nationwide study on the profitability of sheep farming in Germany (2020) demonstrated that over 90% of the revenue from sheep farming is generated through lamb marketing (Korn 2016).

In this study, few significant differences were observed between the two groups. As such, no negative aspects of breeding for shorttails can be identified at this time. As other studies have demonstrated negative aspects of an undocked sheep tail, such as increased incidence of tail vertebrae fractures and tail malformations (Wall 2012), the selection of suitable breeding animals with naturally shorter tails in sheep breeding should be further pursued.

5 | Conclusion

Since a heritability of about 0.60 was determined for tail length (Oberpenning et al. 2022; Greeff, Karlsson, and Schlink 2015), breeding for short tails in a few generations seems promising. It is assumed that breeding for short-tailedness will be widely accepted in society (Lagler et al. 2022), since the mouflon, as a wild form of sheep, has a short, thin tail, just like the ancestors of today's sheep (Shelton 1977; James et al. 1991).

The present study shows that breeding for short-tailedness in Merino sheep is not expected to have a negative influence on reproductive parameters, neonatal vitality and the physical development of lambs up to the 14th week of life.

Author Contributions

Kerstin Brügemann: formal analysis (equal), visualization (supporting) and writing–original draft (supporting). **Hannah Hümmelchen**: investigation (lead), formal analysis (equal), visualization (lead) and writing–original draft (lead). **Sven König**: conceptualization (equal), writing–review and editing (equal). **Henrik Wagner**: conceptualization (supporting), methodology (equal), writing–review and editing (equal). **Axel Wehrend**: project administration (lead), conceptualization (equal), methodology (equal), visualization (supporting) and writing–original draft (supporting).

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Ethics Statement

The authors confirm that the ethical policies of the journal, as noted on the journal's author guidelines page, have been adhered to. The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Regional Council Gießen (V 54—19c 20 15 h 01 GI 18/14 Nr. G 44/2021, 29 September 2021).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data present in this study is available upon request from the corresponding author.

References

Bellof, G., and S. Granz. 2018. *Tierproduktion*, Stuttgart, Germany: Georg Thieme Verlag. https://doi.org/10.1055/b-006-161626.

Bohte-Wilhelmus, D. I., Y. de Haas, J. J. Windig, and R. F. Veerkamp. 2010. "Genetic Selection as Alternative to Tail Docking in Hampshire Down and Clun Forest." *Paper presented at 9th World Congress on Genetic Applied to Livestock Production (WCGALP)*. Leipzig, Germany.

Boscos, C. M., F. C. Samartzi, A. G. Lymberopoulos, A. Stefanakis, and S. Belibasaki. 2003. "Assessment of Progesterone Concentration Using Enzyme Immunoassay, for Early Pregnancy Diagnosis in Sheep and Goats." *Reproduction in Domestic Animals* 38: 170–174. https://doi.org/10.1046/j.1439-0531.2003.00407.x.

Bostedt, H., M. Ganter, and T. Hiepe. 2019. *Klinik Der Schaf- und Ziegenkrankheiten*. Stuttgart, Germany: Georg Thieme Verlag.

Buckingham, K. J., M. J. McMillin, M. M. Brassil, et al. 2013. "Multiple Mutant T Alleles Cause Haploinsufficiency of Brachyury and Short Tails in Manx Cats." *Mammalian Genome* 24: 400–408. https://doi.org/10.1007/s00335-013-9471-1.

DeForest, M. E., and P. K. Basrur. 1979. "Malformations and the Manx Syndrome in Cats." *Canadian Veterinary Journal* 20: 304–314.

Eck, K., E. Kunz, C. Mendel, G. Lühken, and I. Medugorac. 2019. "Morphometric Measurements in Lambs as a Basis for Future Mapping Studies." *Small Ruminant Research* 181: 57–64. https://doi.org/10.1016/j.smallrumres.2019.04.007.

Grant, C. 2004. "Behavioural Responses of Lambs to Common Painful Husbandry Procedures." *Applied Animal Behaviour Science* 87: 255–273. https://doi.org/10.1016/j.applanim.2004.01.011.

Greeff, J. C., L. J. E. Karlsson, and A. C. Schlink. 2015. "Inheritance of Tail Length in Merino Sheep." *Association for the Advancement of Animal Breeding and Genetics* 21: 237–240.

Gür, S., G. Türk, E. Demirci, et al. 2011. "Effect of Pregnancy and Foetal Number on Diameter of Corpus Luteum, Maternal Progesterone

Concentration and Oxidant/Antioxidant Balance in Ewes." *Reproduction in Domestic Animals* 46: 289–295. https://doi.org/10.1111/j.1439-0531.2010.01660.x.

Hümmelchen, H., H. Wagner, K. Brügemann, S. Wenisch, S. König, and A. Wehrend. 2023. "Frequency and Characterisation of Anomalies and Fractures of the Caudal Spine in Sheep With Undocked Tails." *Animals* 13: 1419. https://doi.org/10.3390/ani13081419.

Hümmelchen, H., H. Wagner, S. König, and A. Wehrend. 2022. "Importance of Tail Length in Sheep and the Breeding for Short Tails." *Tierarztliche Praxis. Ausgabe G, Grosstiere Nutztiere* 50: 187–194. https://doi.org/10.1055/a-1851-9402.

Hümmelchen, H., S. Wenisch, K. Brügemann, S. König, and H. W. Wagner. 2023. "Phenotyping the Sheep Tail-Presentation of Methods for Characterization in the Context of Breeding for Short-Tailedness." *Tierarztliche Praxis Ausgabe G, Grosstiere Nutztiere* 51: 6–14.

Hytönen, M. K., A. Grall, B. Hédan, et al. 2009. "Ancestral T-Box Mutation Is Present in Many, but Not All, Short-Tailed Dog Breeds." *Journal of Heredity* 100: 236–240. https://doi.org/10.1093/jhered/esn085.

Indrebø, A., M. Langeland, H. M. Juul, H. K. Skogmo, A. H. Rengmark, and F. Lingaas. 2008. "A Study of Inherited Short Tail and Taillessness in Pembroke Welsh Corgi." *Journal of Small Animal Practice* 49: 220–224. https://doi.org/10.1111/j.1748-5827.2007.00435.x.

James, P. J., D. R. Gare, A. W. Singh, and P. M. Ancell. 1991. "Studies of the Potential for Breeding Short Tail Merinos." *Wool Technology and Sheep Breeding* 38: 106–111.

Jordan, R. M. 1952. "The Description of the No-Tail Breed of Sheep Following Forty Years of Breeding." *Proceedings of the National Academy of Sciences of the United States of America* 31: 103–104.

Karen, A., P. Kovács, J. F. Beckers, and O. Szenci. 2001. "Pregnancy Diagnosis in Sheep: Review of the Most Practical Methods." *Acta Veterinaria Brno* 70: 115–126. https://doi.org/10.2754/avb200170020115.

Korn, S. V. 2016. "Non-Curative Interventions in Sheep and Goats." *Breeding Science* 88: 445–455.

Lagler, D. K., E. Hannemann, K. Eck, et al. 2022. "Medugorac, I. Fine-Mapping and Identification of Candidate Causal Genes for Tail Length in the Merinoland Sheep Breed." *Communications Biology* 5: 918. https://doi.org/10.1038/s42003-022-03854-3.

Oberpenning, J., M. Bohlouli, P. Engel, et al. 2022. "Multiple-Trait and Structural Equation Modelling Approaches to Infer Genetic Relationships Between Tail Length and Weight Traits in Merinoland Sheep." *Journal of Animal Breeding and Genetics* 140: 132–143. https://doi.org/10.1111/jbg.12752.

Pasciu, V., M. Nieddu, E. Baralla, C. Porcu, F. Sotgiu, and F. Berlinguer. 2022. "Measurement of Progesterone in Sheep Using a Commercial ELISA Kit for Human Plasma." *Journal of Veterinary Diagnostic Investigation* 3: 90–93. https://doi.org/10.1177/10406387211043513.

Pollard, J. C., V. Roos, and R. P. Littlejohn. 2001. "Effects of an Oral Dose of Acetyl Salicylate at Tail Docking on the Behaviour of Lambs Aged Three to Six Weeks." *Applied Animal Behaviour Science* 71: 29–42. https://doi.org/10.1016/s0168-1591(00)00170-2.

Robinson, R. 1993. "Expressivity of the Manx Gene in Cats." *Journal of Heredity* 84: 170–172. https://doi.org/10.1093/oxfordjournals.jhered.a111311.

Shelton, M. 1977. "Studies on Tail Length of Rambouillet and Mouflon Sheep." *Journal of Heredity* 68: 128–130. https://doi.org/10.1093/oxfordjournals.jhered.a108788.

Silver, M. 1994. "Placental Progestagens in the Sheep and Horse and the Changes Leading to Parturition." *Experimental and Clinical Endocrinology* 102: 203–211. https://doi.org/10.1055/s-0029-1211284.

Sutherland, M. A., and C. B. Tucker. 2011. "The Long and Short of It: A Review of Tail Docking in Farm Animals." *Applied Animal Behaviour Science* 135: 179–191. https://doi.org/10.1016/j.applanim.2011.10.015.

Von Senden genannt Havercamp, H., H. R. Brandt, and G. Erhardt. 2015. "Variation in Tail Length in Merinoland Sheep as a Basis for Breeding Activities." Lecture presented at the Vortragstagung der Deutschen Gesellschaft für Züchtungskunde e. V. und der Gesellschaft für Tierzuchtwissenschaften e.V., Berlin, Germany.

Wall, R. 2012. "Ovine Cutaneous Myiasis: Effects on Production and Control." *Veterinary Parasitology* 189: 44–51. https://doi.org/10.1016/j.vetpar.2012.03.031.

Washaya, S., U. Ngorio, and C. P. Mudzengi. 2023. "Effects of the Breeding Season, Birth Type and Sex on Growth and Reproductive Performances of Sheep Breeds." *Tropical Animal Health and Production* 55: 188. https://doi.org/10.1007/s11250-023-03575-7.

Wiesner, E., and S. Willer. 1974. *Veterinary Pathogenetics*. Jena, Germany: Fischer.

Wilson, J. W. 1940. "Development of the Notail Sheep." *Agricultural Experiment Station Circular* 25: 3–22.