Pelvimetry and other selected contributing factors causing dystocia in Dorper ewes

by

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Declaration

I, Jan Jacobsz hereby declare the research done in this dissertation for a master's in agriculture and submitted by me, is my own independent work and has not previously been submitted by me or any other university.

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Jan Jacobsz Date

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Dedication

This dissertation is dedicated to my wife Maria Magdalena and three sons, Stefan, Roelof and Johan.

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List of abbreviations

ABT – Average birth time

BA – Birth aid

BS – Birth status

BSW – Birth status of ewe

BW – Birth weight

BWL – Birth weight of lamb

DM – Dohne Merino

DO – Dorper

LCC – Lamb chest circumference

LE – Lambing ease

LES – Lamb ease score

LHC – Lamb head circumference

LPC – Lamb pastern circumference

LS – Litter size

LSW – Lamb shoulder width

PA – Pelvis area

PH – Pelvic height

PW – Pelvic width

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Chapter 1

General introduction

1.1 Introduction

South Africa is primarily a marginal agricultural country. Of the 106 million ha of land available to agriculture, approximately 67% is only suitable for semi-intensive and extensive farming systems. More than 65% of South Africa receives less than 500 mm of rain per annum with a very high level of evaporation (Smit, 1999). This implies that the largest part of the country is only suitable for livestock production. Snyman & Olivier (2002) emphasise the importance of farming with the most suitable type of sheep for these areas in terms of adaptability and profitability.

Profit maximization in a sheep enterprise can be achieved mainly as a result of good reproduction rate, maximum growth rate to slaughter and good quality carcasses produced under natural veld conditions (Zishiri *et al*., 2013). Net reproduction rate, defined as total weight of lamb weaned accumulated over the lifetime of an ewe, is by far the most economically important trait in small stock farming. Despite its importance, this trait is usually ignored during selection of replacement animals (Olivier, *et al*., 2005). Lamb mortality hinders reproduction in sheep flocks worldwide and losses during perinatal (shortly before, during or within 7 days of birth) may contribute up to 80% of such losses (Haughey, 1991). Perinatal deaths, according to Cloete *et al.*, (1998) caused by stressful birth could be attributed to 60% of total loss.

Dystocia is one factor which can cause detrimental losses to a sheep enterprise, and a stock farmer cannot afford losses in an extremely challenging economic climate. Pelvic area is one factor which can be directly measured and selected from both the ewe (direct) and ram (indirect 30 – 60 % influence) (Haughey & Gray, 1982). Dystocia in ewes are associated with small pelvis area, therefore high mortality rates in both ewe and lamb occurs (Kilgour *et al.*, 1993).

The Dorper breed, is internationally renowned for its carcass quality, adaptability, hardiness, good mothering ability, and high overall demand in certain countries worldwide. It is numerically the second most numerous breed with the Merino as the largest sheep breed in South Africa. The Dorper population represents approximately 28% of the 22.2 million sheep in South Africa. This breed not only ranks second in terms of sheep numbers in South Africa, but also realises superior prices at sales and auctions (Milne, 2000).

The Dorper sheep has the ability to adapt to drier regions, withstand dehydration and quickly replenishes body weight losses when water and conditions become more favourable. Dorpers also have the ability to adapt to high temperature regions and are used in mating systems to improve and accelerate the production (Cloete *et al*., 2000).

1.2 Problem statement

Despite its large numbers in South Africa, very little research results have been published on the production and reproduction of Dorpers under extensive conditions. Cloete *et al.* (2000), had come to the conclusion that the Dorper sheep is an adaptable sheep breed that is capable of maintaining acceptable levels of production under a wide variety of conditions. He also stated that there is a lack of information on some aspects of Dorper production. However, the emphasis that was put on conformation and visual appearance, coupled with a lack of objective measuring of animal performance has contributed to some of the problems the breed currently experiences. The following problems further contribute to the problems:

- Dystocia can be caused by small pelvic area to lamb birth weight ratio.
- Rams with small pelvic areas can contribute to dystocia in their offspring.
- Gestation length of the ewe which is determined by the specific ram used to impregnate the ewe can also lead to dystocia.
- Parturition period in the Dorper breed seems to be longer than in other breeds.

1.3 Motivation

The inability to lamb (dystocia) according to Mee (2008), follows when either there is a failure of expulsive force, birth canal inadequacy and fetal size or position. Deutscher (1991) reported that a disproportion between the offspring's birth weight and the dam's pelvic area causes dystocia. This statement is also supported by Cook *et al.* (1993) and Troxel (2008).

Small maternal pelvic size has been associated with dystocia, still-birth and mal-presentation (Cloete *et al*., 1998). According to Briedenhann (2010), a disproportionally large calf size at birth in relation to the mother's pelvic area can be considered as one of the biggest causes of dystocia.

The interaction between the shape and size of the lamb and the ability of the dam to give birth determines the incidence of dystocia (Anderson, 1992). It is concluded that an incompatibility in size between the maternal pelvis and the lamb at birth is largely responsible for the need of assistance at birth (Anderson, 1992) and Patterson and Herring (1997).

Measuring pelvic areas would not be a "cure-all" against lambing problems; however pelvic area measurement is another useful tool in a comprehensive replacement ewe selection programme to reduce dystocia and perinatal instability in lambs and ewes (Troxel, 2008).

Gestation length of sheep varies between 148 to 152 days (Smith, 2006).

The gestation length in Dorper ewes is approximately 147 days and there are reports of 52 days cycling again after parturition (Cloete *et al*., 2000). Gestation length according to Brown (2007) is highly heritable (0.53). He furthermore states that lambing ease and gestation length influence lamb production and are two important factors which play a significant role.

According to Bradford *et al.* (1972), the duration of gestation is determined by two independent sources, namely endocrine function and genetics. The fetal genotype has been proven to determine the duration of gestation although the seasons of the year also play a role. Furthermore, a difference of up to seven days has been recorded between breeds. Pregnancy is generally 150 days (five months). The greater part of foetal growth occurs in the final 60 days; however, setting up effective nutrient transfer from the ewe to the foetus occurs with udder and placental development in the first trimester of pregnancy (Ferguson *et al.,* 2017).

Length of parturition is the period from the first sign of impending birth up to deliverance of the new born. However, ewes that failed to deliver a lamb after four hours need assistance (Cloete *et al*., 1998). In a study done by Cloete *et al*. (1998) on Dormers and SA Mutton Merino ewes, the latter breed took 28.5 minutes longer than the Dormer breed. The SA Mutton Merino took 82.3 minutes compared to the Dormers' 60.8 minutes. According to Dywer (2003), a prolonged labour period reduces lamb survival.

1.4 Aim

The aim of this study is to investigate dystocia and to quantify the correlations between pelvic area to birth weight, parturition period, gestation length and other correlations with pelvic area in young Dorper ewes and then compare these results to those of a breed which does not have mayor dystocia problems like the dual purpose Dohne Merino.

1.5 Study objectives

To determine:

- Dystocia occurrence in young Dorper and Dohne Merino ewes,
- Lambing ease in young Dorper and Dohne Merino ewes,
- Pelvic area to lamb birth weight ratio,
- The differences in pelvic area: lamb birth weight ratios between the Dorper and a double- purpose breed like the Dohne Merino usually not associated with dystocia,
- The parturition period (lambing time of Dorper and Dohne Merino ewes),
- The effect of the sire on gestation period.

1.6 Hypotheses

The three hypotheses associated with the summarised objectives are the following:

- There is a significant difference in the pelvic area of young Dorper and Dohne Merino ewes of the same age.
- Young Dorper ewes are more prone to difficult lambing than Dohne Merino ewes.
- Young Dorper ewes have an unfavourable pelvic area : lamb birth weight ratio.

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Chapter 2

Literature review

2.1 Introduction

2.1.1 Dorper breed

The Dorper breed is a composite between the Black-headed Persian and Dorset Horn and is well known as a South African breed because of its internationally renowned carcass quality, adaptability, hardiness, good mothering ability, and high overall demand in certain countries worldwide. The Dorper breed is an efficient feed converter of pasture and is one of the largest breeds in South Africa (Milne, 2000).

The Dorper is regarded as an early-matured breed, which adapts well to a wide variety of environmental conditions while ewes lamb at an age of approximately one year (Cloete *et al*., 2000). The young Dorper ewes can be mated at an early age of 9 months and its non-seasonal reproduction and reproductive maturity work excellent in an accelerated mating system (Budai *et al*., 2013).

Their fertility ranges around 0.90 ewes lambed per ewe mated and offspring ranging from 1.45 to 1.60 per ewe. Gestation length is approximately 147 days and cycling again after parturition is set approximately at 52 days (Cloete *et al*., 2000). Snyman and Herselman (2005) reported body weight for Dorper ewes at 56.6 ± 1.4 kg and the percentage of lambs weaned agrees with the figures (100%) reported by Cloete *et al*. (2000).

Cloete *et al*. (2000) further reported that the Dorper breed has a pre-weaned survival rate of 90% lambs born and the overall reproduction rate of ewes mated range from 99-140% lambs weaned per ewe. Dorper lambs' average daily weight gain varied between 0.24 to 0.28 kg under hugely different environmental conditions and can be weaned as early as two to three months, thus provides adequate milk production. Dorper ewes weaned lambs of approximately 30 to 39 kg per lamb. Snyman and Herselman (2005) also reported a 40 kg weaning weight. Post weaning gains per day were recorded at 0.18 – 0.20kg and a dressing percentage of approximately 50%, but in most cases the Dorper lamb is being slaughtered at weaning age under favourable conditions to avoid the carcass being classified as too fat (Cloete *et al*., 2000). Snyman and Herselman (2005) stated that a seasonal effect was also evident, as spring born lambs took longer to reach slaughter weight than autumn born lambs. Dorper sheep is frequently being accused of being less selective grazers. Grazing trials on mixed veld in the Eastern Karoo (Middelburg district, South Africa) have proven that the diets overlap between Merino and Dorper to as much as 75% in summer, 92% in spring to 97% in autumn and winter (Snyman & Herselman, 2005). This is in contrast to the finding by Brand (2000) which stated that Dorpers are less selective grazers, ingesting more types of plant species and consume more shrubs and bushes.

Wool production does not form part of the production of Dorper sheep and is seen as a non-wool breed however, a 0.44 to 0.66 kg of greasy wool over an eight month period has been reported with a clean yield of 64.3% (Cloete *et al*., 2000).

2.1.2 Dohne Merino breed

The Dohne Merino has been developed in South Africa as a dual-purpose meat and white wool breed from the German Mutton Merino and the Merino in 1939. The breed has been developed to be an easy care, hardy woollen sheep with a high growth rate and excellent reproductively in the Eastern Cape under harsh sour veld conditions. The Dohne Merino breed was further improved by means of strict scientific selection procedures to develop this breed into an international dual-purpose breed. The breeders' society was founded in 1966 with 2500 ewes (Delport, 2019).

The following objectives and traits are being strived for by breeders: Compulsory performance testing for all breeders; Abolishment of shows; Implementation of Sire Referencing and Estimated Breeding Values (EBV's). The export of embryos worldwide, especially to Australia, ensured that the breed has grown as a dual-purpose breed (Delport, 2019).

The description of the Dohne Merino sheep is a medium to large frame white wool polled breed in both sexes. The Dohne Merino focuses on a smooth body without pleats, face free from kemp, and soft handle white wool with no coloured fibres allowed. The production norms for Dohne Merino ewes are 66kg on average for body weight, 4 kg for greasy wool, 73% clean yield wool which is 2.9kg clean fleece, 19.6 μm fibre diameter, 82.8mm staple length and 32.4 N/Ktex staple strength (Snyman, 2014).

According to Snyman (2014), the following traits for the Dohne Merino rams and ewes at Grootfontein College were recorded: birth weight for rams was 5.2kg and ewes

4.9kg, 100day weaning weights for ram and ewes respectively were 29.9kg and 31.1kg. The 8-month weight for rams was 46.3kg and 37.8kg for ewes and the 12-month weight was 60.3kg for rams and 48.6kg for ewes.

The wool traits on greasy wool reflected a yield of 4.3kg for rams, while the ewes were recorded at 3.7kg with 2.9kg clean wool for rams and 2.6kg for the ewes. In addition, a clean yield of 68.3% for the rams and 70.5% for the ewes were recorded. Staple length in mm for the rams and ewes were recorded respectively at 74.1 and 67.8 mm, fibre diameter in microns for rams 17µm and 16.8 µm for the ewes and staple strength for the rams 35.5 N/Ktex and 32.0 N/Ktex for the ewes (Snyman, 2014).

The average number of lambs born per 100 ewes mated were 130 and lambs weaned per 100 ewes mated were 120. The slaughtering of lambs at a weight of 40kg can be achieved at 4 to 6 months of age. The two most economical products namely meat and wool have the following qualities: lambs can be marketed later due to the fact that the lambs do not accumulate fat at an early stage (Snyman, 2014). According to Delport, (2019) 70% of the breed's income originates from meat and 30% of the income from wool.

2.1.3 Dystocia description in dams

Dystocia happens when one or more of the following three main components are problematic during birth: expulsive force, birth canal capability and fetal size or position (Mee, 2008). According to Statham (2011), dystocia management must begin with proper female development. Calf / lamb birth weight, the size of the pelvic area of the dam and the interrelationship of these two factors are major determinants of dystocia. The weight of the calf or lamb is a function of environmental and genetic factors (sex, length of gestation, breed, heterosis, inbreeding and genotype).

The two major causes of dystocia can normally be classified according to maternal and fetal origins. Most reports show that fetal mal-representation and obstruction of birth canal (especially failure of the cervix to dilate) are the most common causes of dystocia in sheep; and furthermore, that fetal abnormalities, uterine inertia, uterine deviation and uterine torsion also influence dystocia (Purohit, 2006).

Anderson and Bullock (1994) further stated that the single major cause of dystocia is a disproportion between size of the new born at birth expressed in birth weight and the dam's birth canal (pelvic area). The difference in pelvic size is usually attributed to a difference in pelvic height, for instance, when the dam's pelvic height is smaller and the lamb's chest area is bigger the occurrence of dystocia increases. The other factors may also lead to dystocia: birth weight of new born, pelvic area of the ewe, gestation length, sex of the lamb, body condition of the ewe, abnormalities in hormone profiles of the ewe at the time of birth and abnormal presentation of the new born lamb at birth.

Pelvic area can be used as a criterion to cull or selectively breed females. Measuring and calculating internal pelvic area is one of the best ways of predicting dystocia (Waziri *et al*., 2011). Pelvic measurements can be successfully used to identify abnormally small or abnormally shaped pelvises (Deutscher, 1995). Dams with larger pelvic area experienced less dystocia (Waziri *et al*., 2011). Brown (2007) had come to the conclusion that lambing ease scores and gestation length are heritable traits and can be used in the selection criteria to improve lamb survival. Selection for growth, fat and muscle without considering lambing ease could result in a decline of lamb survival.

In particular, dystocia is related to an increase in the postpartum interval, an increase in non-reproductive days, a decrease in overall conception, a decrease in milk production and an increase in metritus and other uterine problems (Walker *et al*., 1992, and Van Rooyen *et al*., 2012). According to Sieber *et al*. (1989), animals that experienced extreme dystocia, produced less milk than animals that experienced no dystocia.

Most lambs' deaths occur within the first day of birth and 75% within three days after birth and are more common in single lambs than in twins. The delivery of one lamb puts more strain on the ewe to expel and can lead to exhaustion and therefore results in the ewe losing interest in the lamb after birth. The upheaval caused by such a difficult birth during lambing can have a negative effect on those ewes that are in the parturition process (Neville, 2007).

According to MacNeil *et al*. (1998), one should select for low birth weights and high subsequent growth at the same time. This can result in genetically improved calving ability. Van Rooyen *et al*. (2012) reported that in Dorper ewes the pelvic width has a greater effect on pelvic area than pelvic height, and that there is a significant difference in pelvic area between type 1 (commercial ewes) to 5 (stud ewes) Dorper ewes. Type

1 ewes had a PA of 33.51 ±3.8 cm^2 as opposed to a PA of 39.97 ±4.3 cm^2 for type 5 ewes.

2.2 Significance of pelvic measurements

Feto-pelvic disproportion (FPD) is any clinically incompatibility between the size or shape of the presenting part of the foetus and the size and shape of the maternal soft tissue. According to Kilgour & Haughey (1993), feto- pelvic disproportion is without doubt a major cause of death during parturition as a result of suffocation associated with prolonged parturition and dystocia. A disproportionally large calf size at birth in relation to the mother's pelvic area is one of the biggest causes of dystocia (Briedenhann, 2010). The maternal causes, according to Purohit (2006), can be grouped into the following: uterine inertia, failure of abdominal expulsive forces and obstruction of the birth canal. Uterine rupture, uterine torsion and pelvic fracture are also part of the maternal causes (35 -38%) and in some other causes up to 50%.

Over time, selection took place for certain conformation traits in Dorpers. Many were to create a more symmetrical animal (Olivier, 2014). It was found by Cloete *et al.* (1998) in SA Mutton Merinos that the rump and shape had a significant correlation with the pelvic surface (the flatter, the smaller the pelvic surface was). Van Rooyen *et al.* (2012) could not find a significant relationship between pelvic area and body measurements like slope of rump, but the size of pelvic area has a significant influence on dystocia and has to be measured directly. It was also reported by Cloete *et al.* (1998) that pelvic surface plays an important role in the occurrence of still born lambs and difficult births. Eighty percent of deaths before weaning occur within 7 days after birth and of these losses, up to 60% can be attributed to difficult births.

Selecting heifers with a large pelvic size, rather than by body weight alone, should be advantageous and should not increase birth weight (Deutscher *et al*., 1991). Deutscher *et al*. (1991) also found that pelvic area is the most reliable yearling trait, indicating potential calving difficulty and has the most influence on dystocia of all cow measurements. Cloete *et al*. (1998) stated that in cattle where the prediction of dystocia is not influenced by multiple births, the pelvic area and birth weight are traits of significant importance.

Small pelvic dimensions in ewes have confirmed to be associated with high levels of dystocia and poor lifetime rearing performance (Kilgour & Haughey, 1993). It would thus make sense to include pelvic area as one of the criteria in selecting breeding ewes; however, measuring in vivo poses some challenges due to the reduced size of the sheep pelvis compared to that of cattle (Van Rooyen *et al*., 2012).

The heritability of pelvic area is high (36 to 68%), while the heritability of pelvis height is greater than the heritability of the pelvic width and pelvic area is more heritable than height and width (Boyles, 2000). Pelvic size of the sire can be up to 60% genetically heritable (Kinne, 2002), thus indicating that the selection for large pelvic size in sires should result in increased pelvic size of the female offspring and pelvic measurements can be successfully used to identify abnormally small or abnormally shaped pelvises (Van Rooyen *et al*., 2012). Pelvic area measurements would not be the cure to all dystocia problems however, pelvic area measurement is another useful tool in a complete replacement ewe selection programme to reduce dystocia and perinatal instability in lambs and ewes (Troxel, 2008). According to Fisher (2003), it will be impractical to focus on only one trait like pelvic indices when selecting replacement ewes and other factors like birth weight should also be considered. According to Dwyer and Lawrence (2005) the rate of still births decreases when the ewes are kept indoors, and the reason is human intervention during prolonged labour.

Certain breeds require more assistance during the lambing period and have longer parturition periods as well. Assistance is then required and the intensity to select naturally for birth ease may be negatively influenced (Burger, 2019).

2.3 Pelvic size and shape

According to Anderson (1992), the interaction between the shape and size of the lamb and the ability of the dam to give birth, determine the incidence of dystocia. It is concluded that incompatibility in size between the maternal pelvis and the lamb at birth is largely responsible for the need of assistance at birth (McSporran & Fielden, 1979, Anderson, 1992 and Patterson & Herring, 1997). Briedenhann (2010) stated that pelvic width is more important in *Bos taurus* cattle and pelvic height more important in *Bos indicus* cattle. This was also reported by Purohit (2006) whereby the feto-pelvic disproportion is common in ewes when the size of the individual lamb is large compared to pelvic area. Purohit (2006) indicated that selective breeding in both ewes and rams appear to be a more effective way of overcoming lambing difficulties.

It should not be assumed that all large-framed females have large pelvic areas or that all small frame females have small pelvic areas.

2.4 Positioning and presentation of the foetus

Abnormal presentations cause some difficulties in lambing. Positioning in a normal presentation is as follows: The feet are presented within an hour or so after the onset of labour and the head follows on top of the knees (Anderson, 1992 and Wilson & Rossi, 2006). There is often a slight delay between the appearance of the feet and the head. After the head is presented, complete delivery should proceed rapidly.

Purohit (2006) reported that in the case of an oversized foetus, especially if the head of the lamb is too big the ewe may become exhausted during the expulsion process. Although the presentation of the lamb was correct, dystocia occurs and, in most cases, the only assistance required is pulling of the forelegs.

The posterior presentation only poses a serious threat when delivery is prolonged. If the hind feet are presented first, allow less time to pass before giving assistance. Slight deviation of one foot or the head can be easily manipulated and corrected, however when more severe deviations occur, expert assistance from a veterinarian may be needed (Anderson, 1992 and Wilson & Rossi, 2006).

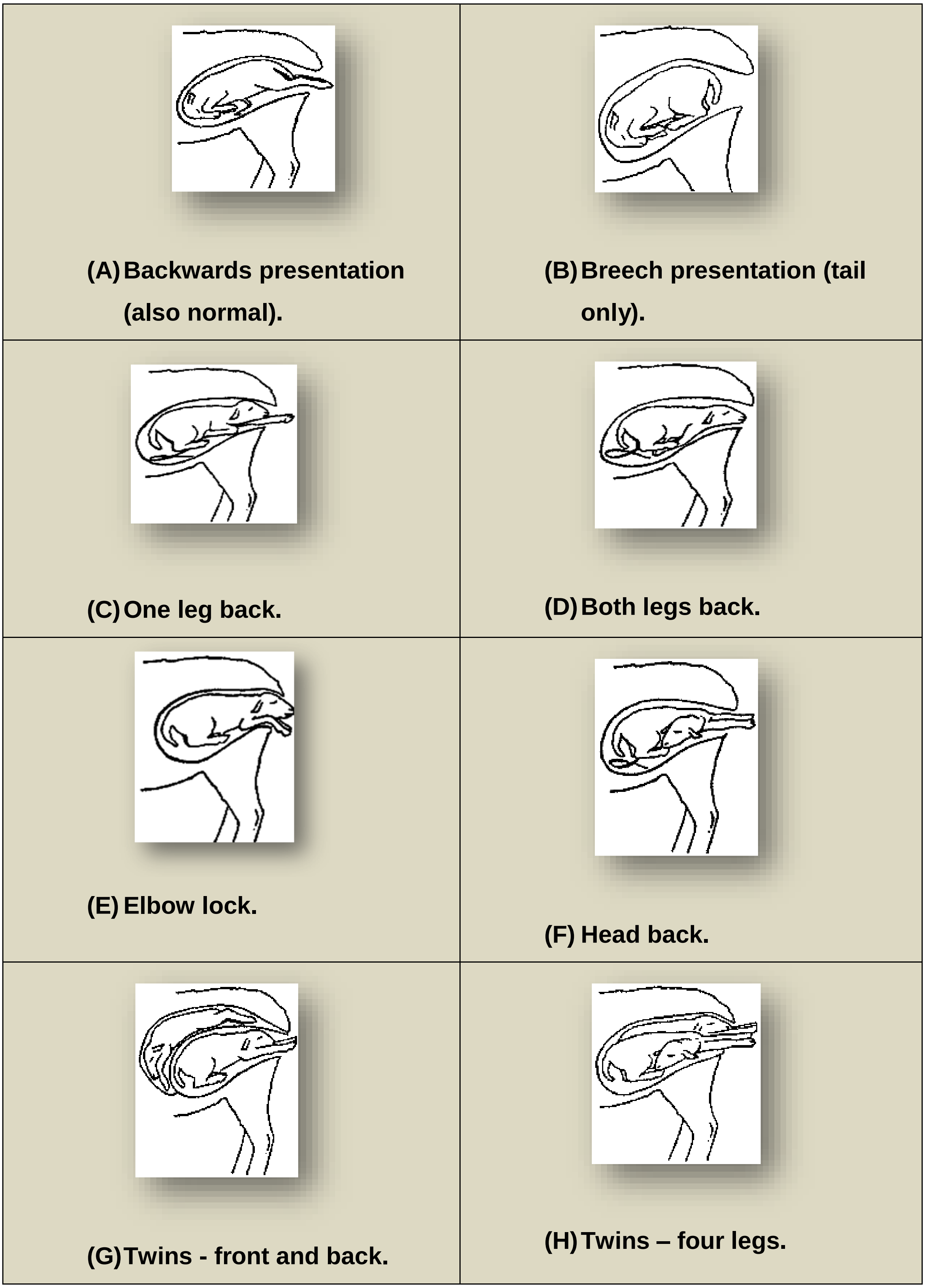

Figure 2.1: A set of figures showing different possible abnormal presentations of the lamb(s) in a ewe (Martin, 2010).

The mal-presentation of the foetus was also reported by Purohit (2006) as a major cause of dystocia with lateral deviation of the head and neck and flexion of the carpus and shoulder being the most common in sheep and abnormal position of limbs where one or both feet retained are some of deviations that cause major dystocia. When the head is deviated downwards and/or laterally to the lamb's body, the ewe can be assisted successfully; especially if the ewe is assisted in the early stage of parturition but if 24 hours is exceeded in stage 2 (explained in 2.19 Parturition period and lambing stages), it might be necessary to remove the limb/s to save the ewe or a caesarean section must be done.

2.5 Effects of dystocia on new-borns

When dystocia occurs acid based imbalances in the foetus can cause mortality due to hypoxia (lack of oxygen) which is caused by contractions and pelvic pressure. New-born lambs are often weak after a prolonged lambing process (dystocia) and find it difficult to stand up suckle the much- needed colostral antibodies from the ewe (Kinne, 2002). According to Kinne (2002),foetuses which were examined post-mortem had the following symptoms: head/neck swelling, haemorrhagic lungs, lungs with meconium fluid, diaphragm rupture, liver rupture, fractures to either legs, jaw, vertebrae, ribs, sternum or back and haemorrhage or congestion of the meninges, all of which are consistently found as possible results of dystocia.

2.6 Possible consequences of dystocia

Failure of abdominal expulsive forces, abdominal wall ruptures, perineal hernias, severe pain or age are all possible causes of dystocia and may need manual assistance (Purohit, 2006). Obstruction of the birth canal of the cervix or the failure of cervical dilation can cause dystocia in up to 50% of sheep. Partial dilation of cervix results in the cervical canal opening only few centimetres and therefore there is obstruction. Purohit (2006) furthermore reported that small pelvic area, pelvic deformity, lack of pre-lambing relaxation of the vulva, vaginal obstruction by scar tissue and vaginal septum, vaginal prolapse, vaginal or vestibular fibrosis, uterine torsion, tumours of the vagina and cervix, cysts and deviation of the uterus can also be causes of dystocia. Vaginal constriction has been reported in 11% of Merino ewes in Australia with a lower reproductive capacity. Uterine torsion is rare in sheep and usually occurs in the early stage of the first stage of labour. Uterine rupture is a frequent cause of death in sheep suffering from dystocia and can result from rolling of ewes suffering from uterine torsion. Administration of oxytocin (uterine echbolics) can also be the cause of uterine rupture or it can occur unexpectedly. Rupture are more likely to happen as a result of excessive traction applied to a foetus which is mal-positioned or oversized in a birth canal which has not opened up (Purohit 2006). Deviation of the uterus or ventral deviation of the uterus may be seen in cases of ventral hernia or rupture of the pre-pubic tendon, and these abnormalities may occur in older heavily pregnant ewes but often in ewes with a poor body condition score. An enlarged abdomen is visible when a spontaneous or traumatic injury takes place whereby uterus falls into the hernia position (Purohit 2006).

2.7 Age and weight of ewe

According to McHaugh *et al*. (2015), ewes lambing for the first time experience a significant higher chance of dystocia than older ewes. The age of the ewe and birth weight of the new born lamb do not have a big influence. The difference between mature and young ewes (old ewes 2-3 years), 4.2 ± 0.4 kg lamb weight versus young ewes (1 year) 4.5 ± 0.4 kg lamb weights (Gardner *et al.*, 2007). When the second lamb is born the next season an average of 136-gram increase in birth weight is reported from the first lamb but a decline after the fourth lamb has been born (Gardner *et al.*, 2007). The recommended weight for a young ewe to be introduced to the ram for first mating is 50 to 70% of adult weight (Gimenez and Rodning 2007).

Van Rooyen *et al*. (2012), found a low correlation of 26% between the weight and pelvic area of the ewe, and therefore heavier ewes would not necessarily have larger pelvic areas.

2.8 Lamb birth weight

Gardner *et al.* (2007) stated that birth weight is influenced by a number of factors like genomes, environmental effects or nutrition, gestation length and sex of the lamb. Litter size will also reflect on the individual weight and the higher number in a litter the lower the individual birth weight, and that litter size overrides all other effects on birth weight. The breed, type of birth, year, ewe age and sex of the lamb influence the birth weight of purebred lambs (Smith 1977). Birth weight in cattle, according to Kinne, (2002), has a 30% heritability. Dystocia increases significantly when birth weights are high. In crossbred lambs up to 30% mortality was recorded with a birth weight of 5.5 kg and as low as 9% when the birth weight was 3.5 kg (Smith, 1977).

An optimum birth weight will ensure uncomplicated natural delivery and low birth weight is associated with the increase of neonatal mortality and high birth weight with complicated lambing (dystocia) and maternal death (Gardner *et al.*, 2007).

2.9 Slope of rump

Cloete *et al*. (1998) found that the slope of the rump did play a role in a study done on SA Mutton Merinos: the flatter the slope of the rump, the longer the ewe will take to lamb; however this phenomenon was not seen in Dorper flocks. Cloete *et al.* (1998), furthermore found that in the SA Mutton Merino the slope of the rump was positively correlated to pelvic area; thus the flatter the rump, the smaller the pelvic area. This was also found in dairy cattle. Van Rooyen *et al.* (2012) reported a non-significant relationship between the slope of the rump and the pelvic area in yearling ewes.

2.10 Dam's pelvic area

According to Purohit (2006), feto-pelvic disproportion is common in ewes when the size of an individual lamb is large compared to pelvic size and appears to be more common in ewes with a single foetus. Low lifetime rearing and the perinatal mortality period (shortly before, during or within seven days after birth) have been associated with the small pelvic area of ewes (Haughey & Gray, 1982). It has also been found by Morrison *et al*. (1986) that dystocia in cattle can be fairly accurately predicted by using the dimensions of the pelvic area and the weight of the foetus.

The pelvis anatomy and pelvis opening of the dam are two important factors to consider for calving ease (Briedenhann, 2010). Walker (1992) reports that the average heritability of pelvic area in cattle is 61%.

According to Cloete *et al*. (1998), the feto-pelvic area disproportion was mentioned as the reason for assistance in more than 50% of the SA Mutton Merino where dystocia of maternal origin was recorded.

Fourie and Van Rooyen (2014) found that the pelvic area of Dorper rams grew rapidly up to 360 days after which it stabilised and stayed the same, thus after 12 to 13 months the pelvic area reached its full potential size.

2.11 Lambing ease

Dwyer and Lawrence (2005) found that lambing ease (LE) has a major impact on lamb survival and growth of a lamb. The faster and easier an ewe can lamb, the better for both the ewe and lamb. The effect of a prolonged parturition period or dystocia will negatively impact the ability to suckle, thus will have a ripple effect which will cause that the lamb cannot heat up which may result in mortality. Lambing ease was positively correlated to birth, weaning and post weaning weight, according to a study by Brown (2007). Sørensen *et al*. (2014) found that a low lambing ease heritability of between 3.8% and 9.7% exists and does not affect the litter size (LS) heritability trait which is 6.4% to 9%. Therefore, there is a non-significant correlation between LE and LS and LE should be included in the selection criteria for replacement ewes.

According to Fourie and Van Rooyen (2014), the lambing ease in Dorper ewes was influenced by the birth status of the dam. Thirty- six percent of ewes born as a single lamb must have been assisted, as opposed to 32% of ewes that were born as one of twins or a multiple birth.

2.12 Gestation length

Gestation length and lambing ease are factors which influence lamb production in a significant way and gestation length was highly heritable at 53 %. Gestation length was genetically positively correlated with birth, weaning and post weaning weight (Brown, 2007). Longer gestation lengths were meaningfully related with worse lamb ease capability in ewes. Brown (2007) furthermore stated that the season of lambing also influenced gestation length and multiple born lambs were associated with shorter gestation length and lower birth weights. Purohit (2006) also reported that a prolonged gestation length results in large sized lambs with a possibility of dystocia. Gestation length in sheep is 147 days (Brown, 2007).

2.13 Body condition score of sheep

The body condition score of ewes before conception has a significant outcome on the lamb's birth weight (Gardner *et al.*, 2007). Gimenez and Rodning (2007) stated that the body condition of the ewe influences reproduction and affects the time puberty starts, conception rate at first oestrus in ewe lambs, length or the postpartum interval and the health and vigour of new-born lambs.

Condition score can be categorised on a scale of 1-5. Thompson and Meyer (1994) described it as follows:

Condition score 1 (emaciated): Spinous processes are sharp and prominent. Loin eye muscle is shallow with no fat cover. Transverse processes are sharp; one can pass fingers under ends. It is possible to feel between each process.

Condition score 2 (thin): Spinous processes are sharp and prominent. Loin eye muscle has little fat cover but is full. Transverse processes are smooth and slightly rounded. It is possible to pass fingers under the ends of the transverse processes with a little pressure.

Condition score 3 (average): Spinous processes are smooth and rounded and individual processes can only be felt with pressure. Transverse processes are smooth and well covered, and firm pressure is needed to feel over the ends. Loin eye muscle is full with some fat cover.

Condition score 4 (fat): Spinous processes can be detected only with pressure as a hard line. Transverse processes cannot be felt. Loin eye muscle is full with a thick fat cover.

Condition score 5 (obese): Spinous processes cannot be detected. There is a depression between fat where spine would normally be felt. Transverse processes cannot be detected. Loin eye muscle is very full with a very thick fat cover.

According to Thompson and Meyer (1994), sheep has different production stages and should have the following optimum body scores: for breeding 3 – 4; early to mid-gestation 2.5 – 4; lambing singles 3 – 3.5; lambing twins 3.5 – 4 and weaning 2 and higher body score.

Van Rooyen *et al*. (2012) found a low correlation of only 10% between body score and pelvic area of the ewe.

2.14 Twins or single lambs

Single-born lambs were heavier at birth and had fewer deaths than multiple born lambs. Single born lambs were also prone to more dystocia than multiple born lambs. Both dystocia and lamb mortality were quadratically related ($P<0.01$) to birth weight (Smith, 1977). Conversely, Gardner *et al.* (2007) stated that the higher the litter size the higher the higher the frequency of mortality becomes. He found that single lambs had a 6.3%, twins 5.2%, triplets 9.8% and quads 20.8% chance of not surviving.

2.15 Sex of lamb

According to Purohit (2006), dystocia occurs most commonly in ewes or does carrying single foetuses. According to Gardner *et al*. (2007), the male offspring is up to 300 - 400 grams heavier than female offspring at birth in sheep and normally the ratio between males and females is 50.5:49.5% favouring the males slightly.

2.16 Sire selection

The sire selection does have a significant effect on lamb birth weight (P < 0.001) and litter size (P <0.05), as stated by Speijers *et al*. (2010). They reported that breeds like Texel- Cheviot- and Lleyn sires which are the meat type of breeds had the most influence on dystocia. Speijers *et al*. (2010) furthermore stated that the Texel breed had a higher proportion of dystocia than the Blackface and the Swaledale but that the level of lamb mortality at birth was not affected by sire breed. The combinations of the larger breeds like Texel and Lleyn sires on Blackface ewes will thus need more assistance during lambing time. There are certain sire traits, for example more meat in hind quarters which are used for terminal crosses which cause dystocia when ewes are lambing (Burger, 2019).

Pelvic size from the sire can be up to 60% genetic heritable, thus indicating that the selection for large pelvic size in sires should result in increased pelvic size of the female offspring and pelvic measurements can be successfully used to identify abnormally small or abnormally shaped pelvises (Kinne, 2002).

The large frame and weight of rams are to blame by some producers. There are sires within each breed, if when mated with certain females, may result in dystocia, and therefore sires should be well chosen. To reduce possible dystocia, sires that produce low birth weight offspring should mate nulliparous animals (Van Rooyen *et al.*, 2012). Although many farmers evaluate breed, structure, frame score and genetics when selecting rams, the dystocia potential of a sire cannot be visually determined. Producers must rely on past birth records or, if available, the expected progeny differences for each sire (Van Rooyen *et al.*, 2012).

2.17 Nutrition

2.17.1 Nutrition of ewe during pregnancy

The nutritional status of the ewe is one factor which the farmer has the most control over, as explained by Gimenez and Rodning (2007). Ewes should be in a good body condition during the breeding season as this will determine the outcome of the next generation. According to Dwyer (2014), undernourishment in pregnancy reduces udder weight and mammary development, delays onset of lactation, reduces colostrum yield and milk production which may lead to an increase of mortality. Ewes which have nutritional distress also display behaviour problems, take longer to interact with their offspring, spend less time grooming them and display more aggression. These ewes spend more time grazing and are more likely to desert their lambs than ewes which are well-fed. Gardner *et al.* (2007) found that there was not a significant influence in birth weight if the ewe was fed an energy source during the early and mid-stage gestation period but there was a significant (P <0.001) influence during the late gestation period. Energy intake is thus important 6 – 8 weeks before conception and during the late gestation period. Under- nutrition will have a >500-gram effect on birth weight. The positive correlation between the ewe's own birth weight and her offspring's birth weight is a trait that may be inherited (Gardner *et al.*, 2007).

2.17.2 Nutrition of new-born lamb

New born lambs will attempt to suckle within half an hour to an hour after being born and weaker lambs longer. The first milk which is called colostrum is very important for the new-born lamb due to the energy, protein and vitamins; especially vitamin A and minerals as well as the very important antibodies which help against infections. Colostrum has a laxative property which helps with the removal of fecal matter. The new-born lamb should consume 10% of body weight within 24 hours and the ability to absorb colostrum decreases after 36 hours (Gimenez & Rodning, 2007).

2.18 Double muscling

Reduced fertility, abnormal structure of the body and respiratory and cardiovascular disadvantages are associated with double muscling. Disproportionate muscling and flat rumps do occur in some Dorper sheep in the hindquarters when compared to other sheep breeds (Van Rooyen *et al*., 2012). Neville (2007) reported that the gallipyge condition does not have the same effect as in cattle to cause dystocia risk. The double muscle gallipyge strains in sheep only show a few weeks after birth and does not present in the foetus. It also does not influence weaning weight and post weaned growth but will improve the feed conversion ratio. It is mainly the muscles in the pelvic area and hind legs that become well developed. Callipyge lambs also have a higher slaughter percentage with more muscle and less fat (Jackson *et al*., 1997).

2.19 Hormones

Increased dystocia was reported by Echternkamp and Gregory (1999), when treatment of progesterone or oestrogen was administered to improve mal-presentation and abnormal presentations of lambs. Supplementing ewes in the last week before lambing with additional energy (750 grams per ewe cracked maize) doubled the mass of colostrum and there were higher concentrations of lactose in the colostrum. Progesterone and growth hormone levels were lower whereas insulin was higher which aid colostrum production, especially for multiple births (Banchero *et al*., 2004).

According to Dwyer (2013), a pregnant ewe needs oestradiol which releases oxytocin in the brain which is important to stretch the vaginal canal. Oxytocin also releases other hormones in the olfactory bulb (identification between ewe and lamb) which is important for maternal behaviour. Amniotic fluids are crucial, especially in young ewes.

2.20 Neurobiology and maternal behaviour

2.20.1 Introduction

Maternal behaviour is governed by neurobiology and the main function is offspring survival, and therefore a range of strategies should be in place, like providing the offspring with nutrition, thermoregulation, protection (both immunological and physical), comfort and social learning. Although there is a strong focus on nutrition which is vital for new-born survival through the ingestion of colostrum, there is a physiological component as well as social learning for the new-born through maternal behaviour (Dwyer, 2013).

2.20.2 Physiology

Physiological processes play a role in coordinating the physical aspect of birth, for example uterine contractions and milk let-down and in stimulating maternal behaviour. In sheep evidence suggests that oxytocin plays a significant role in post-partum stimulation of maternal responses. The importance of the formulation of olfactory (sense of smell) memory and the selective behaviour of the ewe for her own lamb is crucial. There is only a 30-minute window in which the ewe can identify the smell of her own offspring to repel the attempts of other lambs to suckle (Dwyer, 2013).

2.20.3 Maternal experience

Young ewes giving birth for the first time are likely to give birth to smaller lambs and do not show the same level of maternal care as more experienced ewes and therefore the survival rate of such lambs is also lower. Although all the right movements are in place, young ewes are slower to groom and show a higher frequency of behavioural disturbances (Dwyer, 2013).

2.20.4 Genotype effects

According to Dwyer (2013), genotype effects or heritable genetic identity indicates that there are differences between breeds in terms of maternal behaviour which includes their ability to recognise own offspring, willingness to remain at the birth site, lamb rejection and differences in the expression of maternal affiliation. In these studies it showed that the more extensively the herd is being managed, the better natural maternal behaviour presents itself.

2.21 Parturition period and lambing stages

The parturition period can play a significant role with regards to the duration of labour. If the ewe experiences a lengthy labour it can influence the maternal instincts and reduce lamb survival. In such cases ewes are slower to begin grooming their lambs and show reduced grooming behaviour with fewer maternal bleats. Ewes which have had a lengthy parturition period more likely to reject their lambs than ewes delivering after short or uncomplicated births (Dwyer *et al*., 2003; Darwish & Ashmawy 2011).

The parturition period or lambing phases can be described in three stages: stage one starts with the dilation of the cervix, stage two involves the expulsion of the foetus or foetuses and stage three the expulsion of the placenta (Gimenez & Rodning, 2007).

Purohit (2006) found that stage one can last between 6 and 12 hours. Ewes lambing for the first time normally have a longer labour period than older ewes. The process starts when the ewe separates herself from the herd and involves the beginning of uterine contractions and dilation of the cervix. Lack of appetite, according to Bowen *et al*. (2007), is one of the first signs of labour and imminent delivery and the udder fills with colostrum. The pelvic ligaments will loosen, and the ewe will paw at the bedding to push the bedding around to arrange her nest. The ewe will attempt to urinate. The end of stage one is indicated with the appearance of a thick, clear, whitish mucous discharge (Gimenez & Rodning, 2007).

Stage two starts where the ewe lies down on her side with her head in the air or extended forward with front and rear legs touching the ground (Bowen *et al*., 2007). This stage involves the actual birth of the lamb and can take from a few minutes up to three to four hours (Purohit, 2006). According to Bowen *et al*. (2007), this stage should last between 45 to 60 minutes for the first born and 30 minutes between each one (in cases of multiple births), going through the same process of expelling the water and then the lamb. The uterine and abdominal muscles have strong contractions during this stage, and the lamb is ready to be born, nose first alongside the two front feet. As this stage the process accelerates once the head passes the vulva and the lamb is born quickly. Once the lamb is born, the ewe starts cleaning the head and will cease cleaning if there are multiple lambs still to come (Gimenez & Rodning, 2007 & Cloete *et al*., 1998).

Gimenez and Rodning (2007) explain that stage three commences to when the ewe expels the afterbirth or placenta which is a red shiny mass looking like strawberry coloured lumps and may have whitish cords which will expel naturally about two to three hours after final delivery of the lambing process. In multiple births each lamb will have its own placenta and a retained placenta may cause uterine infection. The bonding process will take place between the ewe and lamb or lambs.

2.22 Season of birth

Sheep is seasonal breeders which has an influence on hormones and ovulation. Postpartum eostrus is greatly affected by the season (Gimenez & Rodning, 2007). The external environment or season also influences the birth weight of the lamb (Gardner *et al.*, 2007). Maree and Casey (1993) report that sheep is seasonal breeders and is confined to autumn and winter when the photo-period declines. The correlation between sexual season and light cycles may be related to gestation length, thereby ensuring that the lamb is born when the season is favourable for survival. Sheep breeds that originated from the northern hemisphere have a shorter breeding season and the local Southern Africa breeds have a year-round sexual season although the Dorper and Merino breeds have a reduced summer sexual activity. Birth weight can be influenced by seasons which can cause dystocia (Anderson, 1992).

2.23 Ringwomb in sheep

Ringwomb occurs when the cervix does not relax and expand fully during the birth process. The cervix is the muscular ring at the entrance to the womb. Ringwomb can be divided into two different conditions, namely (1) True ringwomb and (2) False ringwomb. . False ringwomb happens when the cervix does in fact become partly dilated and can be carefully opened manually (Marjorie, 2000).

True ringwomb occurs when the ewe has been straining for hours with no progress and only one or two fingers can enter the womb, although the lamb's two front legs already present themselves in the cervix opening. This is supported by Scott (2010), who reported a 3 to 5 cm opening to the womb. The outside edge of the cervix feels hard and unyielding and feels like a rubber ring and normally a caesarean section must be carried out to save both the ewe and lamb. Some farms or herds experience more cases of true ringwomb and ewes must be culled. The cause is not known, but a genetic component may be involved (Marjorie, 2000).

Marjorie (2000) poses that when the cervix is not fully dilated, which may take up to an hour, premature intervention may result in false ringwomb. The cervix can be gently stretched and worked from side to side and it is not wise to pull too hard on the lamb, which may cause bruising and tearing of the ewe. Scott (2010) warns that trauma to both the new born and the ewe may occur. Secondary uterine inertia is a common result of ring womb and affected ewes have a history of retention of placenta (Purohit 2006).

2.24 Other factors that also have an influence on dystocia

Van Rooyen *et al*. (2012) indicated that other factors may also play a role in dystocia. These include the age of the ram, size of the dam, breed, farm conditions, and the genotype of both the sire and dam.

Furthermore, a low stress environment improves lamb survival and a higher lambing survival percentage can be achieved when management employs good decision-making policies. These include stock policy, selection of pasture for improved feed availability and shelter (Dwyer *et al*., 2003).

Dwyer and Lawrence (2005) furthermore stated that disturbance during birth by human intervention, especially in ewes unaccustomed to human contact can suppress uterine contractions and prolong labour. Therefore, they suggested an alternative approach in which the ewes are left alone; and culling of ewes who needed assistance. This approach resulted in low human intervention or labour without a significant increase in lamb mortality. In other parts of the world like the United Kingdom this will mean initial loss as a result of lamb and ewe mortality but may result in an easy-care sheep flock in the future.

Ewes that are adapted to their environment will fare better than the ones which did not, thus the stock farmer has a duty to provide the ewes with a suitable lambing environment. Stock farmers that fulfil ewes' needs will contribute to ewe welfare which is the underlying feature of easy-care lambing. This can be achieved by the selection of animals that have adapted to their environment (Fisher, 2003).

Kilgour and Haughey (1993) reported that a flock selected for the ability to wean lambs had larger pelvic dimensions than the control group.

Vulva size, according to Gupta *et al*. (2011) in Black Bangle goats measured an average of 26.7 mm in size. Gimenez and Rodning, (2007) describe the vulva to loosen up during lambing.

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Chapter 3

Materials and Methods

3.1 Introduction

This study was conducted using two groups of animals, namely a group of young Dorper ewes managed in the Western Free State and a group of young Dohne Merino ewes in the Southern Free State.

3.2 Environment

3.2.1 Area where the young Dorper ewes were run

The study was conducted in the Petrusburg area in the South Western Free State from October 2017 to May 2019. The dominant vegetation is a grassy, dwarf shrub land. The veld type tends to typical of the false Karoo region and grazing rapidly increases the relative abundance of shrubs. Most of the grasses are deciduous in response to rainfall events (Acocks, 1988). The area is in the grassland biome (Smith, 2006). Temperatures range from an average of 17°C in the winter with many nights below freezing point and the summers to an average of 29°C with hot spells over 40°C. The area is in the summer rainfall region with dry winters. The average rainfall per annum is 433 mm. The rainfall patterns for the last couple of years were below average and the summer rains arrived late in the season. Although the 2019 raining season started late an average rainfall was received.

During late pregnancy ewes were managed semi- intensively although care was taken to prevent that animals become under- or over- conditioned. The ewes stayed in the pens during the last week or two of pregnancy and was managed intensively with clean drinking water and feed available. The ewes were kept in a partially open shed with the north eastern side closed.

Group 1 received the following feeds during the lambing period (four weeks prior till after lambing):

- Maize 110 kg = 22%
- Lucern 250 kg
- Oats 50 kg
- Molasses meal 40 kg
- HPC 50 kg

The ewes received the feeds at a rate of 3% of body weight per ewe per day (approximately 1.7 kg) after an adaption period and received a feed supplement containing 14.83% CP and 9.4 MJ ME/kg DM.

3.2.2 Area where the young Dohne Merino ewes were run

This group was run in the Edenburg area in the Southern Free State from September 2018 to October 2018. The area is in the grassland biome (Smith, 2006). The dominant vegetation is a grassy, dwarf shrub land. Grasses tend to be more common in depressions and on sandy soils, and less abundant on clayey soils. Grazing rapidly increases the relative abundance of shrubs. Most of the grasses are deciduous in response to rainfall events (Acocks, 1988). Temperatures range from an average of 15°C in the winter with many nights below freezing point and the summers to an average of 28°C with hot spells over 35°C. The area is in the summer rainfall region with dry winters. The average rainfall is 344 mm. The rainfall patterns for the last couple of years were below average and the summer rains arrived late in the season. Although the 2019 raining season started late the average rainfall was received.

During late pregnancy and lambing time ewes were managed intensively although care was be taken to prevent that animals get under- or over- conditioned. The ewes were put into pens out in the open but close to the farmhouse and feed shed. The ewes were fed with lamb and ewe feed pellets containing 13% CP and 9.2 MJ ME/kg DM at 3% of body weight which accounts for approximately 1.62 to 2 kg per ewe daily and clean drinking water were available. The biomes of South Africa are illustrated by figure 3 (Sanbi, 2017).

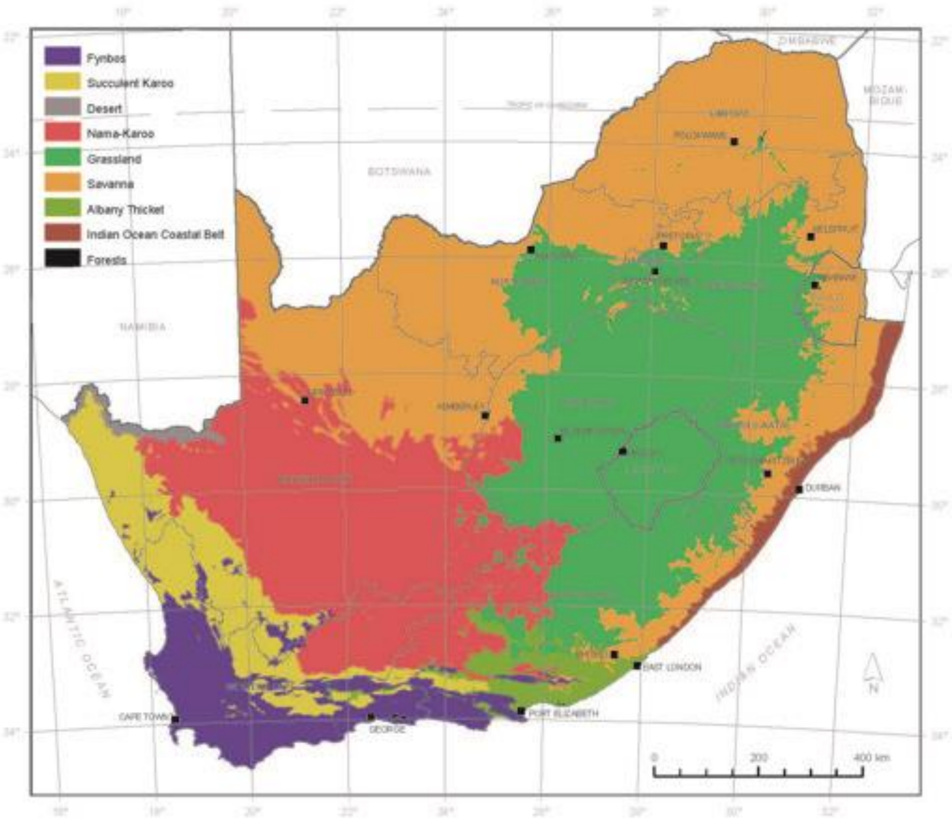

Figure 3.1: Biomes of South Africa

3.3 Animals

3.3.1 Young Dorper ewes

The pelvic area of 369 maiden Dorper stud ewes lambing for the first time were measured for pelvic area approximately two weeks before mating. These ewes were inseminated (laparoscopically) at an average age of 9.31 months.

Recordings included PA, birth weight (BW) of the lamb, birth status of the ewe, circumference of the lamb's head and pasterns, lamb's shoulder width and lambing ease score (LES, 1-6).

3.3.2 Young Dohne Merino ewes

The pelvic areas of 434 young Dohne Merino stud ewes, 18.5 months old, were measured at approximately two weeks before mating time. The ewes were weighed then mated in groups of approximately 60 to one stud ram over a period of two cycles (34 days).

Recordings at lambing time included parturition period, birth weight of the lamb, birth status of the ewe and lamb, circumference of the lamb's head and pasterns, lamb's shoulder width and lambing ease score.

At birth (within 24 hours) the lambs and ewes were weighed using a 10 kg scale for the lambs.

3.4 Instrument

A pelvic meter for sheep developed by Fourie and Van Rooyen at the CUT (Central University of Technology Free State, Patent P59736ZP00) was used for the measurements. This pelvic meter was pre-tested and was found as a reliable instrument to measure the pelvic area of sheep (Figure 3.2) (Fourie, P.J. & Van Rooyen, I.M., 2014).

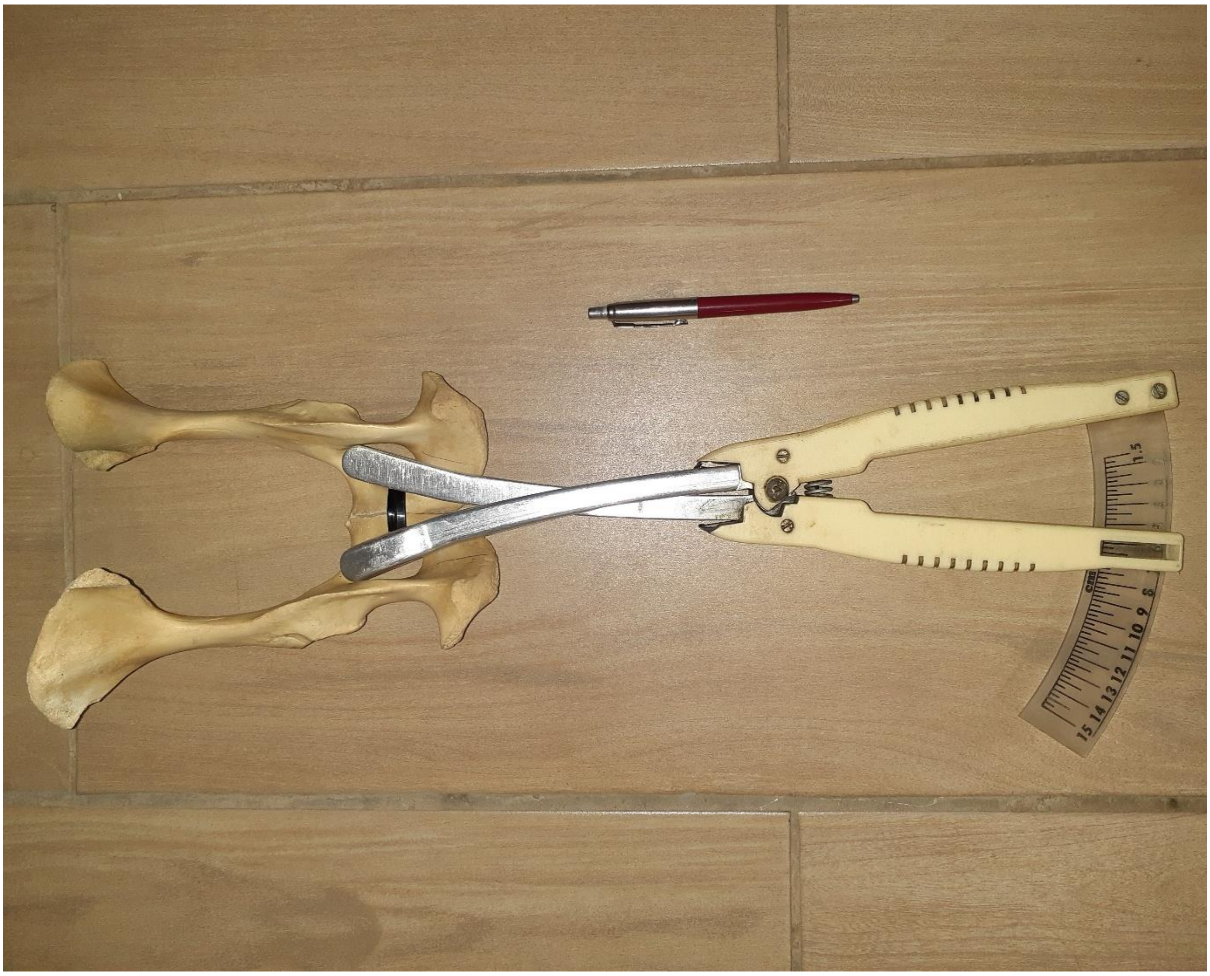

Figure 3.2: Pelvic meter for small stock

3.5 Measurements

3.5.1 Pelvic measurements

Figure 3.3 illustrates the measurements taken of the pelvis. Pelvic height (PH) was taken between the *sacrum* (spinal column) and the *dorsal pubic tubercle* on the floor of the pelvis. Pelvic width (PW) was measured at the widest point between the left and right *ilium* shafts (sides) of the pelvis (Haughey & Gray, 1982; Morrison *et al*., 1986; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Donkersgoed, *et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993).

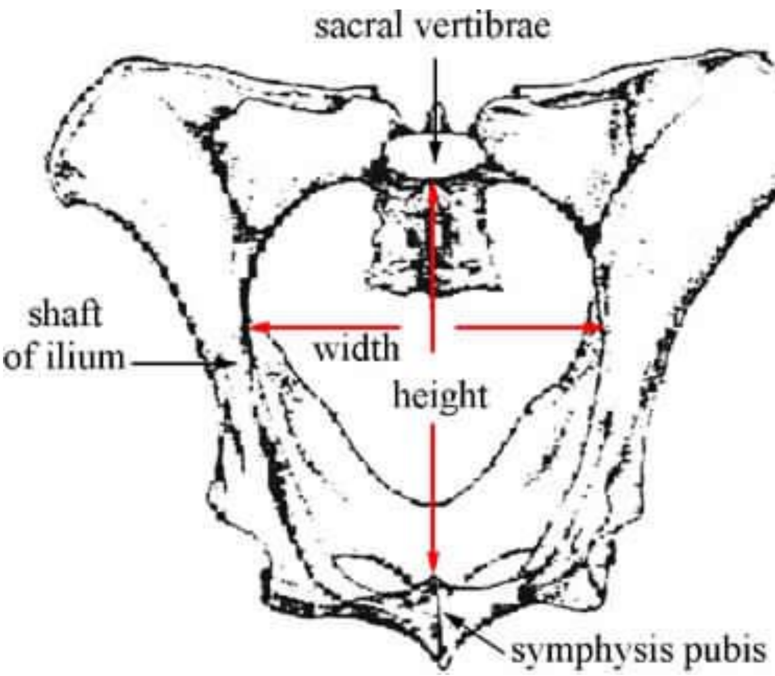

Figure 3.3 Measurement areas for the pelvic area (Anderson & Bullock, 1994).

The general procedure in taking pelvic measurements is to restrain the animal in a chute using a light squeeze. A comfortable, normal standing position is best for this procedure. Faeces was then removed from the rectum if necessary and the instrument was carefully placed into the rectum (Deutscher, 1975). After introducing the instrument into the animal, the instrument was opened while applying light pressure on the handle of the instrument. The instrument was then twisted from left to right to feel the ossified joint on the *pubic symphysis*, as a reference point to measure the height between the *dorsa pubic tubercle* on the floor of the pelvis and the *sacrum* (spinal column) at the top (Figure 3.3). The instrument was then turned 90º sideways to measure the width of the pelvis at widest points between the right and left shafts of the *ilium* bones (Figure 3.3). This is the horizontal diameter of the pelvis (Haughey & Gray, 1982; Morrison *et al*., 1986; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Donkersgoed, *et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993). After that, the instrument was carefully pulled out in the same twisted position to measure the width between the left *tuber ischii* and the right *tuber ischii*. The instrument was then removed from the animal. After every animal the instrument was thoroughly cleaned with water, disinfected with a mixture of gel and disinfectant (Van Rooyen, 2015). All measurements were taken in centimetres.

The pelvises of all the ewes were measured once, using a method adapted from Haughey & Gray, (1982) Kilgour & Haughey, (1993); Patterson & Herring, (1997) and Walker *et al*. (1992). Pelvic area = π (PH/2)*(PW/2) (Morrison *et al.,* 1986).

3.5.2. Ewe measurements:

- Body weight before mating
- Own birth status
- Pelvic area of the ewe
- Gestation length in days (only for Dorpers, as the Dohne Merino ewes were mated in a natural two cycle period during autumn by a single sire group mating).
- Ease of lamb on a scale from 1-6 (Table 1).

Table 3.1: Ease of lamb score, code and description (Brown, 2007).

Score	Code	Description
1	No assistance	Ewe can lamb in the veld or pen without any assistance.
2	Gently pull	Ewe is assisted. Lamb is pulled gently and is pulled out easily.
3	Hard pull	Ewe is assisted. Lamb is pulled hard and difficult to get out but comes out live.
4	Cannot lamb	Ewe cannot lamb. Lamb must be removed from the ewe in an alternative way.
5	Lamb dead	Lamb is dead. Lamb died during birth or died within 48 hours after birth because of difficult birth (not killed by predator).
6	Abnormal foetus position	Lamb is backwards or in an abnormal position (Figure 1 positions A-H).

3.5.3. Lamb measurements:

Recorded for the lambs at birth within 24 hours after lambing:

- Body weight (kg)
- Birth status
- Gender (male, female or combination in case of multiple lambs)
- The circumference of the lamb's head
- Width of the lamb's shoulders.
- Chest circumference on the widest point (mid sternum)
- Pastern circumference
- Birth aid (Yes or No)
- Lamb ease score (LES)
- Monitoring of birth process by making use of CCTV (closed-circuit television) day/night camera. Loveday's infrared camera was installed at a height of 2 m above the lambing pen. This data was recorded to a Loveday DVR with an internal capacity of 2 Gigabyte. A continuous video was taken of the ewes from a week prior to the expected lambing date until the lambing process was done. Parturition times as well as ewe behaviour during the lambing process was available.

Figure 3.4: Measurement of pelvic height in young Dorper ewes

3.6 Capturing of field data

3.6.1 Field data collection

The field data was collected in three stages:

- Pelvic area was measured by the researcher.
- Recording new- born lambs during lambing time was done by a trained designated person on each site under the supervision of the owner of the animals.
- CCTV data was captured by the researcher.

Capturing of data during lambing period in both breeds was partially done by CCTV. The ewes were monitored by a CCTV system with features as seen in table 2 to determine the time of lambing, the parturition period (duration it took for the ewe to expel the lamb) and in the case of dystocia the severity of help by pulling the lamb out. This was recorded according to ease of lambing score scale as seen in table 1 by the trained person on site and then monitored by the researcher through CCTV approximately a week later. The cameras on both sites at group 1 and 2 were approximately 2 meters above the lambing pens.

The first step was to mark all the ewes with a number. Group 1 was marked in red on top of the ewe's back, group 2 was also marked on top of the back, but more than one colour was used, red, blue, green and purple from 1 to 50. Group 1 lambed over more than one season and therefore there were small groups of approximately 20 ewes that lambed every 4 months and they were therefore easy to monitor. Group 2 lambed all within one month and all the ewes were marked on the back, but the lambing pen was also marked.

Figure 3.5: Young Dorper ewes marked on top of back for CCTV monitoring

Figure 3.6: Group of two young Dorper ewes placed in a pen and CCTV camera monitored from above

Figure 3.7: Young Dohne Merino ewes marked on top of the back and the specific pen

The second step was to search for the specific ewe which lambed on the DVR (Digital video recorder) by using the playback function. All ewes that lambed were recorded by the trained person on site and by looking at his data sheet, the specific ewes were easy to find.

The third step was to determine the actual time it took the ewe to lamb. This was done to monitor the ewe in the playback function and to identify when the ewe starts with stage 2 as described by Gimenez and Rodning (2007), Coete *et al*. (1998), Dwyer *et al*. (2003), Darwish and Ashmawy (2011), Bowen *et al*. (2007) and Purohit (2006); from the moment the time was recorded until the lamb was successfully expelled. From the footage it was very clear what the ewe's behaviour was, the number of lambs were easy to identify: whether it was a single, twin or multiple birth; and even if the ewe experienced birth difficulty or received assistance by humans. The lambing ease score was recorded by the trained field person and revaluated by the researcher.

3.6.2 Closed-circuit television (CCTV) Camera features:

Table 3.2: CCTV features

CCTV System:	Love Day-SA
DVR Model:	LD-002
Channel:	8 CH AHD
Power:	External/Eskom
Video clip length	Continuous (5 minutes clips) loop when memory card is full
Videos:	Full color
Software:	I-cloud http://www.topslink.net
Weather housing	Inside shed/Control room
Extra features (stamping on videos)	Time and date
Country of origin:	China
Internal Memory card	
Memory card	Seagate Barracuda Compute
Max memory	1 TB
Country of origin:	Thailand
Cameras:	High definition CCTV camera

Model:	MV-AHDBX612
Pixel:	Megapixel 1.0
Lens:	3.6mm PAL
Power:	DC12V (from external source)
Weather housing	All weather housing (rain resistant)
Country of origin:	China
Cable:	RG59 + Power CCTV Cable
Impedance	75 Ω
Country of origin:	China

3.7 Data analysis

3.7.1 Introduction

Raw data was entered into Ms Excel for decoding before it was entered into the SAS dataset. After the data was checked for mistakes it was analysed. Data was statistically analysed using the SPSS programme (Statistical Package for the Social Sciences) version 25, ANOVA, and the Spearman rho correlation and a regression analysis was conducted (one-way) in order to determine parameters with all variables.

The following assumptions need to be met in order to conduct a regression analysis:

3.7.2 Assumption of a continuous dependent variable

Linear multiple regression assumes that the dependent variable is measured at the continuous level and therefore the dependent variable should be of the interval data type (Field, 2009). Prior research indicated that the Pearson r that is used in linear multiple regression is robust to the violation of the type of scale that is used to measure the dependent variable. Havlicek and Peterson, (1976) and Johnson and Creech (1983) also confirmed that when the ordinal scale that is used to gather data consists of 5 or more categories, multiple regression can still be conducted safely.

3.7.3 Assumption of linear relationship between the dependent variable and the independent variables

Residual plots and scatter plots may be used to indicate linear relationships between independent and dependant variables (Ballance, 2011). The plot of standardised residuals vs unstandardised predicted values of independent variables collectively for the regression model.

3.7.4 Assumption of Normally distributed errors:

It is assumed that the residuals in the model are random, normally distributed variables. P-Plots and histograms (Osborne & Waters, 2002) were used in order to check for normal distribution of errors in the regression model. P-Plots more or less form a straight line and the histograms display an approximate bell curve.

3.7.5 Assumption of homoscedasticity

In order to investigate homoscedasticity of the regression model the scatterplot of the residuals of the independent variables by the predicated value were investigated. The assumption of homoscedasticity was met, meaning that there is equal variance of errors across all levels of the independent variables for the regression model.

3.7.6 Multiple regression

Stepwise multiple regression was selected for the study because stepwise regression is particularly suitable to answer the question of what the best combination of independent variables would be in order to predict the dependent variable (Field, 2009). In a stepwise regression, not all independent variables may end up in the equation. Independent variables are entered into the regression equation one at a time. At each step in the analysis, the independent variable that contributes most to the prediction equation in terms of increasing the multiple correlation, R, is entered first. This process is continued only if additional independent variables add statistically to the regression equation. When no additional independent variables add anything statistically meaningful to the regression equation, the analysis stops (Field, 2009).

3.7.7 Correlations

The strength of the association, for absolute values of r, 0-0.19 is regarded as very weak, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as very strong correlation (The BMJ, 2019).

3.7.8 Hypothesis of correlations

3.7.8.1 Null hypothesis: There is no significant negative correlation between parameters (for example) PA and Birthing Aid (1=no, 2=yes).

3.7.8.2 Alternative hypothesis: There is a significant negative correlation between parameters (for example) PA and Birthing Aid (1=no, 2=yes).

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Chapter 4

Results and discussion

4.1 Introduction

Reproduction worldwide in sheep is being hampered by lamb mortality and losses during the perinatal period (shortly before, during or within 7 days of birth) may contribute up to 80% of such losses (Haughey, 1991). Cloete *et al.* (1998) stated that perinatal deaths caused by stressful birth could be attributed to 60%.

The Dorper breed has recently received negative publicity for its increasing levels of dystocia, especially amongst young maiden ewes. The Dorper ewes that were part of the study were part of a homogeneous group in terms of age, weight when mated and production environment over a period of two and a half years (2017-2019). The Dohne Merino breed (late mature breed) was chosen as a control group due to its little to non-significant level of dystocia. The Dohne Merino ewes were measured, mated and observed during lambing in one season/year (2018).

The management practices that are mainly practised by the respective breeds were followed. The Dorper ewes were mated at 9.31 months (Budai *et al*., 2013) and the Dohne Merino ewes were mated at the age of 18.5 months.

4.2 Pelvic area measurements

The pelvic area of Dorper ewes (DO) measured 33.45 ± 3.12 cm^2 (pelvic area still expanding till 12 to 13 months of age). Van Rooyen *et al*. (2012) reported a mean pelvic area in yearling Dorper ewes of 35.55 cm^2. The Dohne Merino ewes (DM) measured bigger (P <0.01) with 36.61 cm^2 ± 3.64 at mating (Table 4.1).
Deutscher *et al*., (1991) also found that pelvic area is the most reliable yearling trait indicating potential calving difficulty and it has the biggest influence on dystocia of all cow measurements. Pelvic height in DO measured 6.58 ± 0.36 cm and 6.7 ± 0.43cm in DM ewes respectively. The pelvic width measured 6.46 ± 0.36 cm and 6.93 ± 0.39cm in DO and DM ewes respectively. Briedenhann (2010) stated that pelvic width is more significant in *Bos taurus* cattle while pelvic height is more significant in *Bos indicus* cattle. Van Rooyen *et al*. (2012) found similar results in DO ewes where the pelvic height (PH) was bigger than pelvic width, thus the DO ewes have the same traits as *Bos indicus* cattle and DM ewes display similar pelvic dimensions than *Bos Taurus cattle*.

The ratio between Pelvic Area (PA) and Birth weight (BW) of the lambs were more favourable (P <0.05) in DO ewes (9.69 cm^2 :1 kg lamb born) than in DM ewes (7.64 cm^2 : 1 kg lamb born), but despite the more favourable ratio in DO ewes, more (P <0.05) ewes (67%) needed assistance as opposed to only 1% of DM ewes (table 4.1). Deutscher (1995) also emphasised the importance of pelvic area to calf birth weight ratio these ratios are useful in predicting which heifers may require assistance during calving.

Table 4.1: Pelvic parameters mean (± SD) of the young Dohne Merino and Dorper ewes

Parameters	Dorper	Dohne Merino
Pelvic Height	6.58 ± 0.36^a	6.7 ± 0.43^b
Pelvic Width	6.46 ± 0.36^a	6.93 ± 0.39^b
Pelvic Area (cm^2)	33.45 ± 3.12^a	36.30 ± 3.92^b
Pelvic Area : Birth Weight ratio	9.69^a	7.64^b

Means with different superscripts within the same row differ significantly (P <0.05)

The Birth Status (BS) and PA of ewes are illustrated in Figure 4.1. A significant (P <0.01) difference in PA between the ewes which were born as one of a single lamb, twin or triplets was clear. Dorper and Dohne Merino ewes' PA's measured in cm^2 were as follows: a single 33.44 cm^2 & 36.03 cm^2, twin 34.02 cm^2 & 36.73 cm^2 and triplet 35.57 cm^2 & 36.16 cm^2. In both breeds the twins measured larger (P <0.05) but especially the DO ewes measured linearly larger when the ewe was one of a multiple birth. These results are in agreement with Fourie and Van Rooyen (2012) who found that Dorper ewes that were born one of a twin or multiple lambs experienced less dystocia when she lambed herself. Fourie and Van Rooyen (2012) furthermore found that 36% ewes that were born as a single lamb required assistance during lambing and 32% for ewes that were born as a twin or multiple lamb.

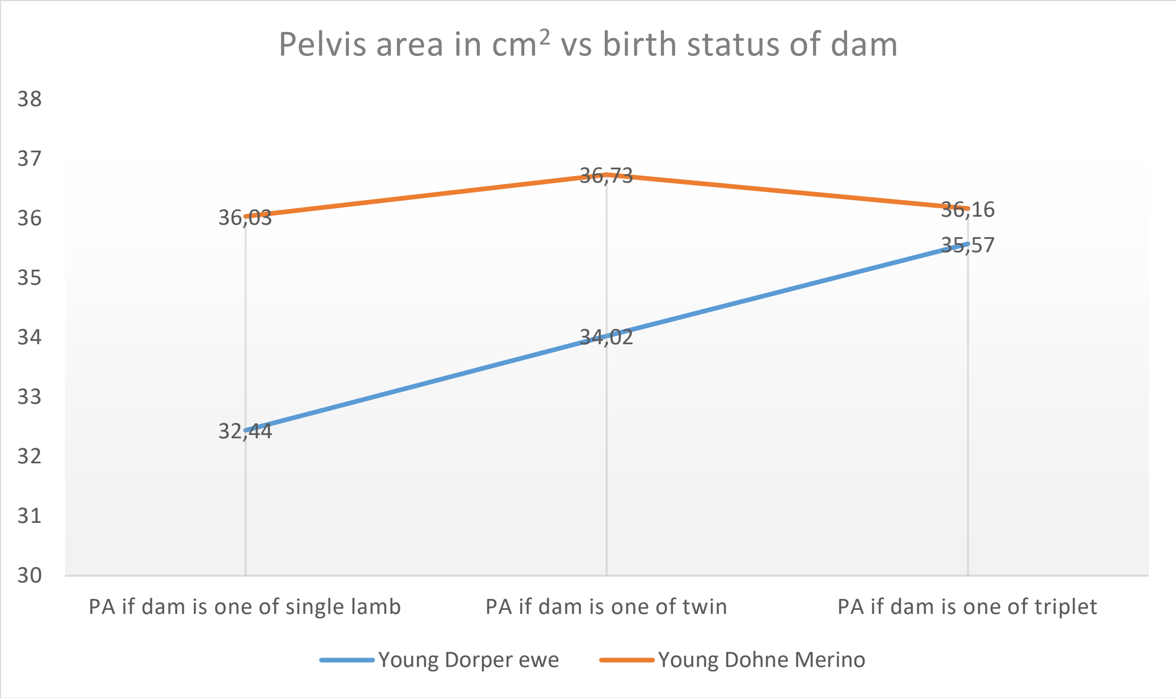

Figure 4.1: Size of the pelvic area in cm^2 and birth status of the dam.

4.3 Parameters of ewes influencing dystocia

Dorper and DM ewes' mating age differed (*P* <0.05) with 15.31 ± 1.68 months for DO and 23.07 ± 3.21 months for DM respectively (Table 4.2). The mating weight also differed (*P* <0.05) with DO ewes weighing 52.32 ± 6.35 kg. Van Rooyen *et al*. (2012) recorded a similar mating weight of 48 kg for Doper ewes. Conversely, the DM ewes weighed 57.42 ± 3.76 kg.

Table 4.2: Mean (± SD) for age, mating weight, parturition period, gestation length and percentage ewes assisted

Parameters	Dorper	Dohne Merino
Age at lambing (months)	15.31 ± 1.68[a]	23.07 ± 3.21[b]
Mating weight / kg	52.32 ± 6.35[a]	57.42 ± 3.76[b]
Parturition period stage 2	52.22 ± 37.34 [a]	63.11 ± 47.51 [a]
Gestation length (days)	146.21 ± 1.81	N/A
Percentage ewes assisted	67 [a]	1 [b]

Means with different superscripts within the same row differ significantly (*P* <0.05)

The DO ewes took 52.22 ± 37.34 min (67% human intervention after an hour) and DM ewes 63.11 ± 47.51 min (1% human intervention within 8 hours) on average to expel the new-born lamb as measured from the start of stage two of parturition (Table 4.2). In the case of these lengthy parturition periods the ewes are more likely to reject their lambs than ewes delivering after short or uncomplicated births (Dwyer *et al*., 2003; Darwish and Ashmawy 2011). Gestation length was only possible to record for DO ewes (146.21 ± 1.81 days) as the DM ewes were group mated.

4.4 Correlations of parameters in Dorper- and Dohne Merino ewes

4.4.1 Dorper ewes

Dorper ewes recorded correlations from very low (0.19) to very high (0.89) between ewe parameters (Table 4.3). Pelvic area (PA) and pelvic width (PW) has a very high correlation of 0.89 (P <0.01) similar to PA and pelvic height (PH) with a correlation of 0.81 (P <0.01) which is expected as PA is a function of PH and PW. Van Rooyen *et al*. (2012) also found the correlations between PA to PW and PH to be high, 84% for pelvic height and a very high 94% for pelvic width. Kinne (2002) found that pelvic area is between 50 – 60% heritable, about twice the heritability of birth weight of 30%.

Birth status of the ewe (BSE) and PA have a low positive correlation of 0.38 (P <0.01) which points out another advantage of selecting for twin or multiple birth replacement ewes (Figure 4.1). Fourie and Van Rooyen (2012) found that Dorper ewes had bigger pelvic areas if they were born one of a twin or multiple birth.

Average birth time (ABT) and birth weight of the lamb (BWL) are positively correlated (0.50; P <0.01), the less the lamb is weighing the quicker the ewe will deliver the lamb (Table 4.3). Dwyer and Lawrence (2005) also stated that lamb survival is influenced by the birth weight of the new-born lamb.

Average birth time and birth aid (BA) (less aid required during lambing when parturition period was shorter) were also moderately correlated (0.46; P <0.01). Average birth time and LES were also positively correlated 0.49 (P <0.05) (the shorter the parturition period the easier the ewe lamb with a lower/better score on the LES score card). Dwyer and Lawrence (2005) also stated that lamb survival is influenced significantly by the time the ewe takes to deliver the lamb. The BWL and BA were positively correlated (0.46; P *<0.01*), less aid was therefore needed when BWL was lower (Table 4.3).

Table 4.3: Correlations of parameters between the young Dorper ewes above the diagonal and young Dohne Merino ewes below the diagonal

Parameter	PA	ABT	BWL	PH	PW	BA	LES	BSE
PA		-0.12	-0.059	**0.814**	**0.892**	-0.108	-0.126	**0.383**
ABT	0.019		**0.501**	-0.121	-0.069	**0.457**	**0.494**	-0.192
BWL	-0.016	**0.364**		-0.072	-0.032	**0.461**	**0.535**	0.050
PH	**0.870**	-0.065	-0.042		**0.499**	-0.134	-0.179	**0.454**
PW	**0.758**	0.132	0.021	**0.368**		-0.061	-0.045	**0.194**
BA	0.028	0.157	0.151	0.028	-0.011		**0.806**	-0.195
LES	0.019	0.101	0.099	0.012	-0.014	**0.893**		-0.122
BSE	0.140	-0.099	-0.095	0.128	0.077	-0.011	0.028	

PA = Pelvis area, ABT = Average birth time, BWL = Birth weight of lamb, PH = Pelvis height, PW = Pelvic width, BA = Birthing Aid, LES = Lambing ease score, BSE = Birth status of ewe

Lambing ease score and BWL were positively 0.53 (P <0.01) correlated. Pelvic height and PW also have a positive correlation of 0.49 (P <0.01). Pelvic height and BSE are also correlated positive moderately 0.45 (P <0.01). A low positive correlation of 0.19 (P <*0.05*) was recorded between PW and BSE.

4.4.2 Dohne Merino ewes

A low correlation of 0.36 (P <0.05) between BWL and ABT were recorded for the DM ewes (Table 4.4); therefore, less time was needed for a ewe to lamb when the BWL was lower. Dwyer and Lawrence (2005) reported that lamb survival increases when the time the ewe takes to deliver is less.

Pelvic height and PW were positively correlated (P <0.01) to PA, 0.87 and 0.75 respectively as both these parameters are used to calculate pelvic area (PA). Pelvic width (PW) are weakly correlated to PH (0.36; P <0.01). Van Rooyen *et al*. (2012) also found the correlations between PA to PW and PH to be high, 84% for pelvic height and a very high (94%) for pelvic width.

From Figure 4.1 it is also evident that when the birth status of ewe's changes from a single born lamb to a twin or multiple birth the pelvic area also increases, which is in agreement with the results of Fourie and Van Rooyen (2012).

4.5 Regression model

The regression model with independent variables (Table 4.4) indicate the parameters that had the most influence on lambing ease. The lambs' head circumference 16% (*P* <0.05), average birth time 0.07% (*P* <0.05) and birth weight of the ewe 25% (*P* <0.05) was the only variables that had an influence.

Table 4.4: Independent variables that influence lambing ease in both Dorper ewes and lambs'

Variables	LES
Lamb head circumference	0.165
Average birth time	0.007
Birth weight of ewe	-0.255
Pelvic area	N/S
Pelvic height	N/S
Pelvic width	N/S
Gestation lenght	N/S
Ewes' weight when mated	N/S
Lambs' shoulder width (cm)	N/S
Lambs' chest circumference (cm)	N/S
Lambs' pastern circumference (cm)	N/S
R^2	0.243

4.6 Parameters of new-born lambs

The birth weight of Dorper lambs (DOL) measured 3.70 ± 0.85 kg and Dohne Merino lambs (DML) 4.85 ± 1.13 kg which differed (*P* <0.01) from one another. Dystocia increases significantly when birth weights are high and in crossbred lambs an up to 30% mortality was recorded with a birth weight of 5.5 kg and as low as 9% when the birth weight was 3.5 kg (Smith, 1977). Birth weight in sheep is 30% heritable according to Massey and Vogt (2019).

Shoulder width in DOL (8.19 ± 9.04 cm) differed (*P* <0.01) from DML (7.04 cm ± 10.07), the pastern circumference also differed (*P* <0.01) between the two breeds with DOL measuring 8.34 ± 0.89 cm and DML 9.19 ± 0.62 cm (Table 4.4).

The lambs' head circumference (LHC) and lambs' chest circumference (LCC) did not differ (*P* >0.05) from one another other in DOL measuring 25.03 ± 1.70 cm and DML 25.26 ± 1.55 cm respectively for head circumference and 36.02 ± 4.36 and 36.76 ± 3.88 for DOL and DML respectively for chest circumference (Table 4.4). Purohit (2006) reported ewes with oversized lambs which were presented normally got exhausted during parturition and the lamb got stuck with only the head presented in the birth canal.

Table 4.5: Mean (± SD) of new -born Dorper and Dohne Merino lambs

Parameters	Dorper	Dohne Merino
Lamb birth weight (kg)	3.70 ± 0.85^{a}	4.85 ± 1.13^{b}
Lambs' shoulder width (cm)	8.19 ± 9.04^{a}	7.04 ± 10.07^{b}
Lambs' head circumference (cm)	25.03 ± 1.70^{a}	25.26 ± 1.55^{a}
Lambs' chest circumference (cm)	36.02 ± 4.36^{a}	36.76 ± 3.88^{a}
Lambs' pastern circumference (cm)	8.34 ± 0.89^{a}	9.19 ± 0.62^{b}

Means with different superscripts within the same row differ significantly (*P*<0.05)

4.7 Correlations of parameters in Dorper and Dohne Merino lambs

4.7.1 Dorper lambs

From Table 4.5 it can be derived that Birth aid (BA) and lamb head circumference (LHC) have a moderate positive correlation of 0.47 (*P* <0.01) which means the lamb's head circumference significantly contributed to aid during the birth process. Lambing ease score and LHC showed a medium correlation (0.53; *P* <0.01). The size of the lamb's head made a significant contribution to the regression model by predicting 53% of the variability in LES. Birth aid had a weak positive correlation with lamb pastern circumference (LPC) (0.20; *P* >0.05).

Lamb chest circumference (LCC) and BA had a moderate correlation of 0.45 (*P* <0.01). Lamb chest circumference (LCC) and (LES) correlated positively (0.54; *P* <0.01). From these parameters LCC and LHC recorded the highest correlation of (0.79; *P*

<0.01). Lamb pastern circumference (LPC) correlated moderately positive 0.48 (*P* <0.01) with LCC and (0.37, *P* <0.01) low positive with LHC.

Lamb shoulder width (LSW) had a significant (*P* <0.01) and positive correlation with the following parameters: 0.49 with BA, 0.45 with LES, 0.48 with LHC, 0.44 with LPC and 0.59 with LCC. Sørensen (2014) found that lambing ease is a heritable trait and can be used to genetically improve the ewe herd.

Table 4.6 Correlations of lambing ease score and lamb parameters with Dorper lambs above the diagonal and Dohne Merino below the diagonal

Parameter	BA	LES	LHC	LPC	LCC	LSW
BA		**0.806**	**0.478**	**0.209**	**0.457**	**0.492**
LES	**0.893**		**0.535**	**0.236**	**0.541**	**0.458**
LHC	0.136	0.105		**0.379**	**0.799**	**0.489**
LPC	0.153	0.123	**0.627**		**0.486**	**0.448**
LCC	0.090	0.061	**0.617**	**0.599**		**0.593**
LSW	0.048	0.045	**0.294**	**0.333**	**0.535**	

BA = Birth Aid, LES = Lamb ease score, LHC = Lamb head circumference, LPC = Lamb pastern circumference, LCC = Lamb chest circumference, LSW = Lamb shoulder width

4.7.2 Dohne Merino lambs

A very high correlation between LES and BA of 0.89; (*P* <0.01) was recorded. Lamb head circumference (LHC) and LPC as well as LHC and LCC had a strong positive correlation of 0.62 (*P* <0.01) and 0.61 (*P* <0.01) respectively. Lamb pastern circumference (LPC) and LCC were moderate positively correlated (0.59; *P* <0.01). Lastly the lamb chest circumference (LCC) and LSW parameters correlated moderate positively 0.53 (*P* <0.01) (Table 4.5).

4.8 Sire influence on birth weight and gestation length

The influence of the sire on the birth weight and gestation length is significant (Speijers *et al*. (2010) and was one of the study objectives. The results from this study indicated no effect (*P* >0.05) from the sires that were used in both treatment groups. Gestation length could only be determined in the DO due to the laparoscopic method of impregnation. In this study sire did not have an effect (*P* >0.05) on either birth weight or gestation length.

4.9 Other parameters of Dorper and Dohne Merino lambs

The ratio of male and female is indicated in Figure 4.2. A normal distribution of 50% was almost achieved with 54% of the DM lambs being male and 46% being female, while 53% of the DO lambs were male and 47% female. The correlation between sex of the lamb and LES was non-significant (*P* >0.05). Therefore, the mothers of ram lambs did not have more difficulty to lamb.

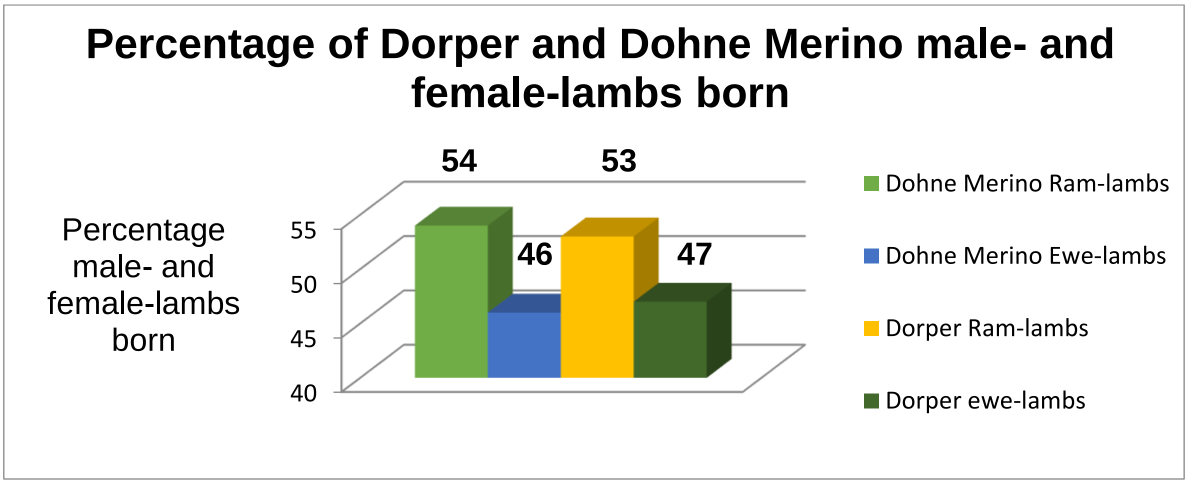

Figure 4.2: Percentage Dorper and Dohne Merino male- and female-lambs born.

From Figure 4.3 it can be depicted that The Dohne Merino ewes (30.29%) had a higher percentage of twins than the Dorper ewes (19.28%). The Dohne Merino breed strongly select for twins which is clearly visible from the data. A medium negative correlation (-0.48; *P* <0.05) was found between LES and Birth status of the lamb. This indicates that ewes lambed easier when she lambed twins.

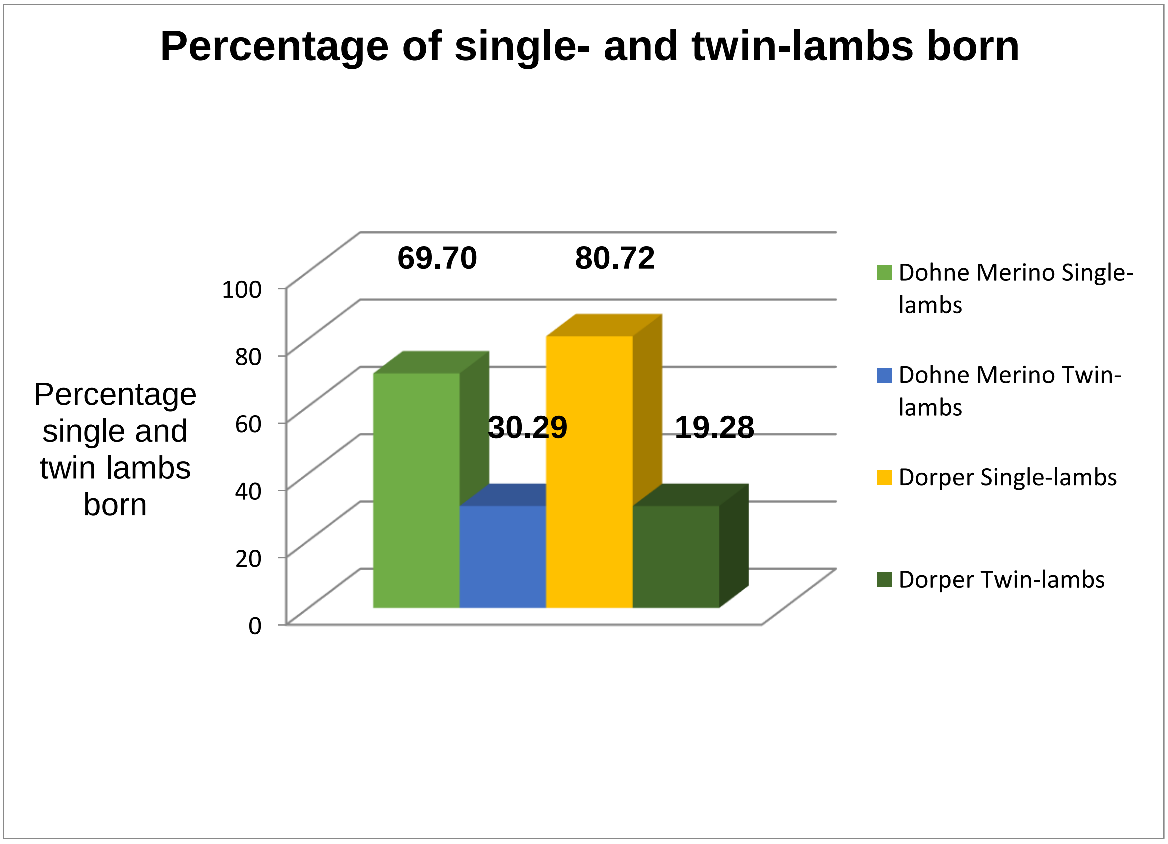

Figure 4.3: Percentage single and twin lambs born from the young Dorper and Dohne Merino ewes

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Chapter 5

Conclusions and Recommendations

5.1 Summary

The Dorper breed is recognised internationally for its carcass quality, adaptability, hardiness, good mothering ability, and high overall demand in certain countries worldwide (Milne, 2000). The Dorper is an early maturing breed (Cloete *et al*., 2000) and efficient converters of natural resources/veld into meat. In most cases young Dorper ewes wean a lam by the time the Dohne Merino ewes are mated.

Young Dohne Merino ewes (dual purpose breed) produce a quality wool clip, lamb easily and the fertility of the breed is above average with a high twinning percentage, with the two most economical products being meat and wool. The breed has the advantage of lambs that can be marketed later due to the fact that the lambs do not accumulate fat at an early stage (Snyman, 2014).

5.2 Conclusions Dorpers

The pelvic area of Dorper ewes measured 33.45 cm^2 with a mating weight of 52.32 kg at an age of 9.31 months and a lambing age of 15.31 months. The ratio between PA and BWL 9.69 cm^2 : 1 kg lamb born in the DO, which is more favourable when compared to the DM. The ewes that was born as a single lamb measured 32.44 cm^2 that area increased as the birth status increased to one of twins (34.02 cm^2) and if one of a triplets to 35.57 cm^2 which indicate that if the farmer select for multiples the pelvic size may increase.

The young Dorper ewes took 52.22 minutes to deliver on average but 67% of the ewes needed assistance, keeping in mind that the management only allowed approximately an hour before human intervention to prevent losses. Mortality would have occurred in a significant percentage of the ewes and lambs if they haven't been assisted. It can also be assumed that the actual parturition period would have been much longer if the ewes were not assisted after one hour.

Average birth time and birth weight of the lamb are moderately positive correlated ($r = 0.50$) which indicate that the lower the birth weight the faster the young Dorper ewe will lamb. Birth weight of the lamb and lambing ease score was also 28% correlated to each other and a 29% correlation between the lambs' head and chest circumference. The size of the lamb's head (16%), the average birth time (0.07%) and birth weight of ewe (25%) made a significant contribution to the regression model of the variability in LES.

The lambs that has been born 53% were males and 47% female, twinning was 19.28%. In most cases the parameters of the DO ewes and lambs were more favourable than those of DM ewes, better PA:BWL ratio, lower BWL except the LSW that differ significantly (P <0.05) between the breeds in favour of the DM lambs. It is evident that the DO lambs' shoulder with was 1.15 cm wider even though the DM lambs were nearly 1.2kg heavier. However, the DM ewes showed by far the least percentage of dystocia. This may be an indication that the Dorper has some form of conformational dysfunctionality.

5.3 Conclusions Dohne Merino

The Dohne Merino ewes are fertile with a high libido (Delport, 2019). The ewes' pelvic area measured 36.3 cm^2 and had a mating weight of 57.42 kg, and lambed at an age of 23.07 months. The ratio between PA and BWL was 7.64 cm^2:1 kg lamb born. The young DM ewes took 63.11 minutes to deliver on average and only 1% required assistance.

The correlations with the lamb parameters was lamb head circumference which was 61% correlated with chest circumference and 62% with pastern circumference. Chest circumference also had a moderate correlation of 59% with pastern circumference and 53% with shoulder width. The majority of the lambs were male (54%) and twinning was 30.29%. Only 1% dystocia was recorded.

5.4 Recommendations

5.4.1 Dorpers

- Selecting for twins or multiple births as replacement ewes may result in bigger pelvic areas which may reduce dystocia in the long run;
- The conformation of the Dorper should be re assessed in terms of functionality with special reference to lambing ability.
- The body dimensions of the lambs is a contributing factor to dystocia experienced in the breed.
- The replacement rams and ewes' pelvic measurements should be part of the selection criteria because pelvic area and shape must be recorded;

- It must be considered to mate the young ewes a month or two later as it could help with the development of the young ewe before she lambs;
- The influence of the sire on gestation length should be investigated on a larger group of animals to determine the effect;
- The feeding strategy of the farmer needs attention because the body condition score of the young ewes are above the recommended 3 – 3.5 body condition score (Thompson and Meyer, 1994). Body condition score of the ewe will also have an effect of the birth weight of the lambs;

5.4.2 Dohne Merino

- The inclusion of birth weights as a standard parameter to the breed requirements when tagging new-born lambs will add value to the data set.

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Addendum A

Pelvimetry and other selected factors causing dystocia in young Dorper and Dohne Merino ewes

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Abstract

The aim of this study was to measure pelvic area in maiden Dorper and Dohne Merino ewes and to determine its effect on lambing ease, birth aid, parturition period and pelvic area to lamb weight ratio. The ewes' pelvic dimensions as well as the new born lambs' external body measurements of both breeds were taken to determine the effect on lambing. Three hundred and sixty-nine (369) young Dorper ewes *ca* 9.31 months old, weighing approximately 52.32 kg and four hundred and thirty-four (434) Dohne Merino ewes *ca* 18.5 months old, weighing approximately 57.42 kg were used for this study. Pelvic area of the young Dorper- measured 33.45 ± 3.12 cm^2 and 36.30 ± 3.92 cm^2 for young Dohne Merino respectively. Pelvic area was calculated using the π (PH/2)*(PW/2) formula. The pelvic area of ewes born as one of twins measured bigger than that of a single born lamb in both breeds. Young Dorper ewes took 52.22 ± 37.34 min (67% assistance) and young Dohne Merino ewes 63.11 ± 47.51 min (1% assistance) to lamb. Pelvic area to birth weight ratio was 9.69 cm^2 to 1 kg lamb born and 7.64 cm^2 to 1 kg lamb born in Dorper and Dohne Merino ewes respectively. Significant correlations between lambing ease score and other parameters were recorded in ewes and lambs. It was concluded that Dorper lamb parameters correlated between 20% to 80% with one another and the effect on lambing ease was influenced the most by the lambs' head circumference (16%), average birth time (0.07%) and birth weight of ewe 25% with an R^2 of 0.243.

Keywords: Birth aid, lambing ease, maiden ewes, parturition period, pelvic area

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Introduction

Reproduction worldwide in sheep is being hampered by lamb mortality and up to 80% of losses may occur during the perinatal period (within seven days of birth, just before or during) (Haughey, 1991). The Dorper breed has recently received negative publicity for its increasing levels of dystocia, especially amongst young maiden ewes. Assistance at birth may be described as the incompatibility maternal pelvis size and the lamb which cause dystocia and follows when either there is a failure of expulsive force, birth canal adequacy and fetal size or position (Mee, 2008). Deutscher (1991) reported that a disproportion between the offspring's birth weight and the dam's pelvic area causes dystocia. Small maternal pelvic size has been associated with dystocia, still-birth and mal-presentation (Cloete *et al*., 1998). According to Dywer, (2003) prolonged parturition period reduces lamb survival. Selection of replacement ewes that were born as one of a twin or multiple birth can decrease dystocia due to the larger pelvic area of these ewes (Fourie and Van Rooyen, 2012). Van Rooyen *et al*. (2012) found a low correlation of 26% between weight and pelvic area of the ewe, and therefore heavier ewes would not necessarily have larger pelvic areas. Dystocia increase significantly when birth weights are high (Smith, 1977). Van Rooyen *et al*. (2012) reported a non-significant relationship between the slope of the rump and the pelvic area in yearling ewes. In 50% of dystocia cases which was reported by Cloete *et al*. (1998) the South African Mutton Merino breed suffered from a feto-pelvic area disproportion.

Measuring pelvic areas is a useful tool in ewe selection to reduce dystocia and perinatal instability in lambs and ewes. Pelvic area is between 50 – 60% heritable (Kinne, 2002). Sørensen *et al*. (2014) found a low lambing ease (LE) heritability of between 3.8% and 9.7% exists and does not affect the litter size (LS) heritability trait which is 6.4% to 9%. Therefore, a non-significant correlation between LE and LS and LE should be included in the selection criteria for replacement ewes. According to Fourie and Van Rooyen (2014) the lambing ease in Dorper ewes was influenced by the birth status of the dam. Thirty-six percent of ewes born as a single lamb must have been assisted as opposed to 32% of ewes that were born as one of twins or multiple birth. The body condition score of ewes before conception have a significant outcome on the lamb's birth weight (Gardner *et al*., 2007).

The aim of this study was to use pelvic area measurements, birth weight, parturition period, and external body measurement of new born lambs to identify the main sources of dystocia in maiden ewes. Furthermore, the lambing ease of young Dorper ewes were critically compared with those of young Dohne Merino ewes as it is a breed known for ease of lambing.

Materials and Methods

Three hundred and sixty-nine (369) young Dorper- *ca* 9.31 months old, weighing approximately 52.32 kg and four hundred and thirty-four (434) Dohne Merino ewes *ca* 18.5 months old, weighing approximately 57.42 kg were used for this study. Both Dorper and Dohne Merino ewes were stud animals and their body condition score (BCS) ranged between 3 and 4. The management practices followed by the respective breeds were applied. The Dorper ewes were inseminated laparoscopically in seven groups over a period of two years and the Dohne Merino ewes were group mated with a single sire in one season (Autumn 2018) only. During late pregnancy the Dorper ewes were managed semi intensively although care was taken to prevent that animals get under or over conditioned. The ewes stayed in the pens (partially open shed with the north eastern side closed) during the last week of pregnancy and received a feed supplement containing 14.83% CP and 9.4 MJ ME/kg DM (3% of body weight per ewe per day) and clean drinking water.

The Dohne Merino ewes were supervised intensively (lambing pens out in the open) during late pregnancy and lambing time. The ewes were fed with lamb and ewe feed pellets containing 13% CP and 9.2 MJ ME/kg DM at 3% of body weight which accounts for approximately 1.62 to 2 kg per ewe daily. Clean drinking water was freely available. The pelvic areas of the ewes of both breeds were measured (using a pelvic meter, Patent P59736ZP00) pre-mated to calculate the pelvic area. The pelvic height (PH) was taken by measuring the distance between the sacrum (spinal column) and the dorsal pubic tubercle on the floor of the pelvis. The pelvic width (PW) measurement was taken at the widest point between the left and right ilium shafts (sides) of the pelvis (Haughey & Gray, 1982; Morrison *et al*., 1986; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Donkersgoed, *et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993). Pelvic area was calculated using the formula π (PH/2)*(PW/2).

The pelvic measurements were taken with the following general procedure. Firstly, the animal was restrained in a light manual squeeze by assistants while maintaining a comfortable, normal standing position. Secondly, residual faecal matter were removed from the rectum if present, after which the instrument was carefully placed intra-rectally (Deutscher, 1975). Once the clean disinfected instrument was lubed it was introduced gently into the ewe's rectum. Light pressure on the handle of the instrument from left to right enable the researcher to identify the ossified joint of the pubic symphysis by feel, which was then used as a reference point to measure the height between the dorsa pubic tubercle on the floor of the pelvis and the sacrum (spinal column) at the top. Once the reference point was identified, the instrument was then be turned 90º sideways angle to measure the width of the widest points between the right and left shafts of the ilial bones. This pelvic width measurement equals the horizontal diameter of the pelvis (Haughey & Gray, 1982; Morrison *et al*., 1986; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Donkersgoed*, et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993). The final measurement was done by withdrawing the instrument slightly with a twisting motion and then measuring the width between the left tuber ischii and the right tuber ischii. Once all measurements were complete, the instrument was withdrawn gently from the animal. Finally, the instrument was thoroughly cleaned with clean water and disinfectant before use in the next animal (Van Rooyen, 2015). All measurements were taken in centimeters. The following measurements were recorded: body weight before mating, ewe's own birth status, pelvic area of the ewe, gestation length in days (only for Dorpers, Dohne Merino ewes were mated in a natural two cycle period during autumn by a single sire group mating) and lambing ease on a scale from 1-6 (Table 1).

Table 1 Lambing ease of lamb on a scale

Score	Code	Description
1	No assistance	Ewe can lamb in the veld or pen without any assistance.
2	Gently pull	Ewe is assisted. Lamb is pulled gently and is pulled out easily
3	Hard pull	Ewe is assisted. Lamb is pulled hard and difficult to get out but comes out live.
4	Cannot lamb	Ewe cannot lamb. Lamb must be removed from the ewe in an alternative way.
5	Lamb dead	Lamb is dead. Lamb died during birth or died within 48 hours after birth because of difficult birth (not killed by predator).
6	Abnormal foetus position	Lamb is backwards or in an abnormal position

Source: (Brown, 2007).

The following measurements were taken from the new born lambs within 24 hours after the ewes lambed. The body weight (BWL), birth status (BSL), gender (G), circumference of the lamb's head

(LHC), width of the lamb's shoulders (LSW), chest circumference (LCC) on the widest point (mid sternum), and pastern circumference (LPC). The monitoring of the birth process was done by making use of CCTV (closed-circuit television) day/night camera. Loveday's infrared camera was installed at a height of 2 m above the lambing pen. This data was recorded to a Loveday DVR with an internal capacity of 2 Gigabyte. Continuous video was taken of the ewes from a week prior the expected lambing date until the lambing process was completed. Parturition time and ewe behavior during the lambing process was available.

The non-parametric Mann-Whitney test was used to test for differences between groups. Analysis of variance were conducted to determine the statistical significance of the variables using SPSS. A stepwise regression analysis was carried out to determine the individual influence of parameters on LES. Statistical significance was set at (P <0.05). Ethical clearance number UFS-AED2018/0051, date 9 October 2018.

Results and Discussion

The pelvic area of Dorper ewes (DO) measured 33.45 ± 3.12 cm^2. Van Rooyen *et al*. (2012) reported a mean pelvic area in yearling Dorper ewes of 35.55 cm^2. The Dohne Merino ewes (DM) measured bigger (P <0.01) with 36.61 cm^2 ± 3.64 at mating (Table1).

Deutscher *et al*. (1991) also found that pelvic area is the most reliable yearling trait indicating potential calving difficulty and it has the biggest influence on dystocia of all measurements. Pelvic height in DO measured 6.58 ± 0.36 cm and 6.7 ± 0.43 cm in DM ewes respectively. The pelvic width measured 6.46 ± 0.36 cm and 6.93 ± 0.39 cm in DO and DM ewes respectively. Briedenhann (2010) stated that pelvic width is more significant in Bos taurus cattle while pelvic height is more significant in Bos indicus cattle. Van Rooyen *et al*. (2012) found similar results in DO ewes where the pelvic height (PH) was bigger than pelvic width, thus the DO ewes have the same traits as Bos indicus cattle and DM ewes display similar pelvic dimensions than Bos Taurus cattle.

The ratio between pelvic area and birth weight of the lamb were more favourable (P <0.05) in DO ewes (9.69 cm^2 : 1 kg lamb born) than in DM ewes (7.64 cm^2 : 1 kg lamb born), but despite the more favourable ratio in DO ewes, more *(P* <0.05) ewes (67%) needed assistance as opposed to only 1% of DM ewes (Table 2). Deutscher (1995) also emphasised the importance of pelvic area to calf birth weight ratio, these ratios are useful in predicting which heifers may require assistance during calving.

Table 2 Pelvic parameters mean (± SD) of the young Dohne Merino and Dorper ewes

Parameters	Dorper Mean ± SD	Dohne Merino Mean ± SD
Pelvic Height	6.58 ± 0.36^a	6.7 ± 0.43^b
Pelvic Width	6.46 ± 0.36^a	6.93 ± 0.39^b
Pelvic Area (cm^3)	33.45 ± 3.12^a	36.30 ± 3.92^b
Pelvic Area : Birth Weight ratio	9.69^a	7.64^b
Age at lambing (months)	15.31 ± 1.68^a	23.07 ± 3.21^b
Mating weight / kg	52.32 ± 6.35^a	57.42 ± 3.76^b
Parturition period stage 2	52.22 ± 37.34 ^{a}	63.11 ± 47.51 ^{a}
Gestation length (days)	146.21 ± 1.81	N/A
Percentage ewes assisted	67 ^{a}	1 ^{b}

Means with different superscripts within the same row differ significantly (P <0.05)

Dorper and DM ewes' mating age differed (P <0.05) with 15.31 ± 1.68 months for DO and 23.07 ± 3.21 months for DM respectively (Table 2). The mating weight also differed (P <0.05) with DO ewes weighing 52.32 ± 6.35 kg. Van Rooyen *et al*. (2012) recorded a similar mating weight of 48 kg for Dorper ewes. Conversely, the DM ewes weighed 57.42 ± 3.76 kg. The DO ewes took 52.22 ± 37.34 min (67% human intervention after an hour) and DM ewes 63.11 ± 47.51 min (1% human intervention within 8 hours) on average to expel the new-born lamb as measured from the start of stage two of parturition (Table 2). In the case of lengthy parturition periods the ewes are more likely to reject their lambs than ewes delivering after short or uncomplicated births (Dwyer *et al*., 2003; Darwish and Ashmawy 2011). Gestation length was only possible to record for DO ewes (146.21 ± 1.81 days) as the DM ewes were group mated.

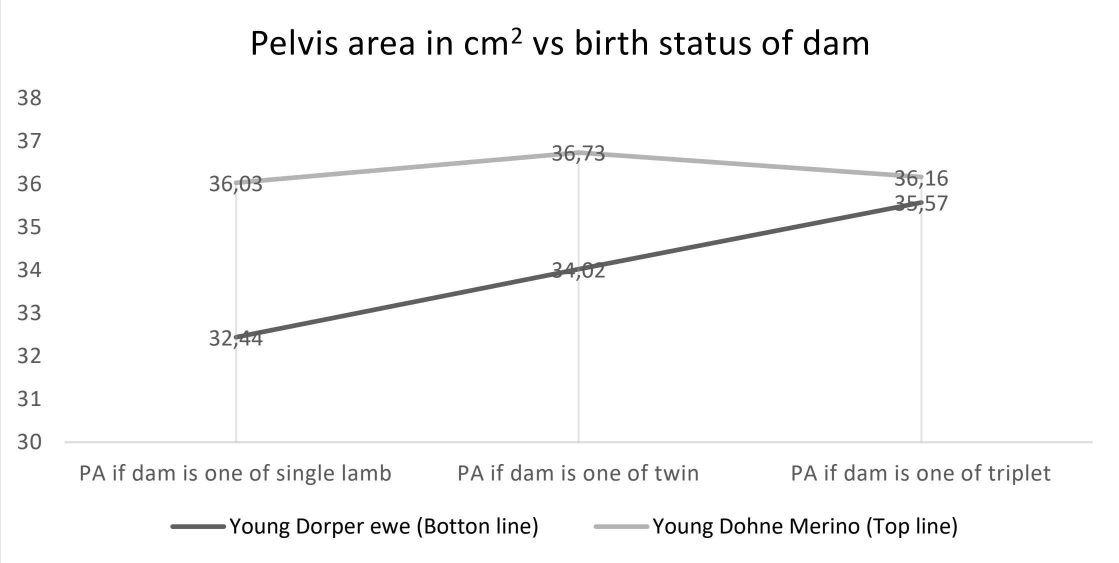

Figure 1 The size of the pelvic area in cm^2 and birth status of the dam.

The Birth Status (BS) and PA of ewes are illustrated in Figure 1. A difference (*P* <0.01) in PA between the ewes which were born as one of a single lamb, twins or triplets was clear. Dorper and Dohne Merino ewes' PA's measured in cm^2 were as follows: a single 33.44 cm^2 & 36.03 cm^2, twin 34.02 cm^2 & 36.73 cm^2 and triplet 35.57 cm^2 & 36.16 cm^2. In both breeds the twins measured larger *(P* <0.05), but especially the DO ewes measured linearly larger when the ewe was one of a multiple birth. These results are in agreement with Fourie and Van Rooyen (2012) who found that Dorper ewes that were born one of a twin or multiple lamb experienced less dystocia when they lambed themselves. Fourie and Van Rooyen (2012) furthermore found that 36% ewes that were born as a single lamb required assistance during lambing and 32% for ewes that were born as a twin or multiple birth.

Table 3 Mean (± SD) of new -born Dorper and Dohne Merino lambs

Parameters	**Dorper**	**Dohne Merino**
Lamb birth weight (kg)	3.70 ± 0.85[a]	4.85 ± 1.13[b]
Lambs' shoulder width (cm)	8.19 ± 9.04[a]	7.04 ± 10.07[b]
Lambs' head circumference (cm)	25.03 ± 1.70[a]	25.26 ± 1.55[a]
Lambs' chest circumference (cm)	36.02 ± 4.36 [a]	36.76 ± 3.88 [a]
Lambs' pastern circumference (cm)	8.34 ± 0.89 [a]	9.19 ± 0.62 [b]

Means with different superscripts within the same row differ significantly (*P*<0.05)

The birth weight of Dorper lambs (DOL) measured 3.70 ± 0.85 kg and Dohne Merino lambs (DML) 4.85 ± 1.13 kg which differed (*P* <0.01) from one another. Dystocia increases significantly when birth weights are high and in crossbred lambs up to 30% mortality was recorded with a birth weight of 5.5 kg and as low as 9% when the birth weight was 3.5 kg (Smith, 1977). Birth weight in sheep is 30% heritable according to Massey and Vogt (2019).

Shoulder width in DOL (8.19 ± 9.04 cm) differed (*P* <0.01) from DML (7.04 cm ± 10.07), the PCL also differed (*P* <0.01) between the two breeds with DOL measuring 8.34 ± 0.89 cm and DML 9.19 ± 0.62 cm (Table 3).

The lambs' head circumference (LHC) and LCC did not differ (*P* >0.05) between the treatment groups. DOL measuring 25.03 ± 1.70 cm and DML 25.26 ± 1.55 cm respectively for head circumference and 36.02 ± 4.36 cm and 36.76 ± 3.88 cm for DOL and DML respectively for chest circumference (Table 3).

Dorper ewes recorded correlations from very low (0.19) to very high (0.89) between ewe parameters (Table 3). Pelvic area (PA) and pelvic width (PW) has a very high correlation of 0.89 (*P*

<0.01) similar to PA and pelvic height (PH) with a correlation of 0.81 (*P* <0.01) which is expected as PA is a function of PH and PW. Van Rooyen *et al*. (2012) also found the correlations between PA to PW and PH to be high, 84% for pelvic height and a very high 94% for pelvic width. Kinne (2002) found that pelvic area is between 50 – 60% heritable, about twice the heritability of birth weight of 30%. Birth status of the ewe (BSE) and PA have a low positive correlation of 0.38 (*P* <0.01).

Average birth time (ABT) and birth weight of the lamb (BWL) are positively correlated (0.50; *P* <0.01), the less the lamb weighs the quicker the ewe will deliver the lamb (Table 4). Dwyer and Lawrence (2005) also stated that lamb survival is influenced by the birth weight of the new-born lamb. Average birth time and birth aid (BA) (less aid required during lambing when parturition period was shorter) were also moderately correlated (0.46; *P* <0.01). Average birth time and LES were also positively correlated 0.49 *(P* <0.05) (the shorter the parturition period the easier the ewe lamb with a lower/better score on the LES score card). Dwyer and Lawrence (2005) also stated that lamb survival is influenced significantly by the time the ewe takes to deliver the lamb. The BWL and BA were positively correlated (0.46; P <0.01), less aid was therefore needed when BWL was lower (Table 4). Lambing ease score and BWL were positively 0.53 (*P* <0.01) correlated. Pelvic height and PW also have a positive correlation of 0.49 (*P* <0.01). Pelvic height and BSE are also correlated positive moderately 0.45 (*P* <0.01).

Table 4 Correlations of parameters between young Dorper ewes above the diagonal and young Dohne Merino ewes below the diagonal

Parameter	PA	ABT	BWL	PH	PW	BA	LES	BSE
PA		-0.12	-0.059	**0.814**	**0.892**	-0.108	-0.126	**0.383**
ABT	0.019		**0.501**	-0.121	-0.069	**0.457**	**0.494**	-0.192
BWL	-0.016	**0.364**		-0.072	-0.032	**0.461**	**0.535**	0.050
PH	**0.870**	-0.065	-0.042		**0.499**	-0.134	-0.179	**0.454**
PW	**0.758**	0.132	0.021	**0.368**		-0.061	-0.045	**0.194**
BA	0.028	0.157	0.151	0.028	-0.011		**0.806**	-0.195
LES	0.019	0.101	0.099	0.012	-0.014	**0.893**		-0.122
BSE	0.140	-0.099	-0.095	0.128	0.077	-0.011	0.028	

PA = Pelvis area, ABT = Average birth time, BWL = Birth weight of lamb, PH = Pelvis height, PW = Pelvic width, BA = Birthing Aid, LES = Lambing ease score, BSE = Birth status of ewe

A low correlation of 0.36 *(P* <0.05) between BWL and ABT were recorded for the DM ewes (Table4); therefore, less time was needed for a ewe to lamb when the BWL was lower. Dwyer and Lawrence (2005) reported that lamb survival increases when the time the ewe takes to deliver is less.

Pelvic height and PW were positively correlated (*P* <0.01) to PA, 0.87 and 0.75 respectively as both these parameters are used to calculate pelvic area (PA). Pelvic width (PW) are weakly correlated to PH (0.36; *P* <0.01). Van Rooyen *et al*. (2012) also found the correlations between PA to PW and PH to be high, 84% for pelvic height and a very high (94%) for pelvic width.

From Table 5 it can be derived that birth aid (BA) and lamb head circumference (LHC) have a moderate positive correlation of 0.47 (*P* <0.01) which means the lamb's head circumference significantly contributed to aid during the birth process. Lambing ease score and LHC showed a medium correlation (0.53; *P* <0.01). The size of the lamb's head 16% (*P* <0.05), the average birth time 0.07% (P <0.05) and birth weight of the ewe 25% (*P* <0.05) made a significant contribution to the regression model of the variability in LES. Birth aid had a weak positive correlation with lamb pastern circumference (LPC) (0.20; *P* >0.05). Lamb chest circumference (LCC) and BA had a moderate correlation of 0.45 (*P* <0.01). Lamb chest circumference (LCC) and (LES) correlated positively (0.54; *P* <0.01). From these parameters LCC and LHC recorded the highest correlation of (0.79; *P* <0.01). Lamb pastern circumference (LPC) correlated moderately positive 0.48 (*P* <0.01) with LCC and (0.37, *P* <0.01) low positive with LHC. Lamb shoulder width (LSW) had a significant (*P* <0.01) and positive correlation with the following parameters: 0.49 with BA, 0.45 with LES, 0.48 with LHC, 0.44 with LPC and 0.59 with LCC. Sørensen *et al*. (2014) found that lambing ease is a heritable trait and can be used to genetically improve the ewe herd.

Table 5 Correlations of lambing ease score and lamb parameters with Dorper lambs above the diagonal and Dohne Merino below the diagonal

Parameter	BA	LES	LHC	LPC	LCC	LSW
BA		**0.806**	**0.478**	**0.209**	**0.457**	**0.492**
LES	**0.893**		**0.535**	**0.236**	**0.541**	**0.458**
LHC	0.136	0.105		**0.379**	**0.799**	**0.489**
LPC	0.153	0.123	**0.627**		**0.486**	**0.448**
LCC	0.090	0.061	**0.617**	**0.599**		**0.593**
LSW	0.048	0.045	**0.294**	**0.333**	**0.535**	

BA = Birth Aid, LES = Lamb ease score, LHC = Lamb head circumference, LPC = Lamb pastern circumference, LCC = Lamb chest circumference, LSW = Lamb shoulder width

Lamb head circumference (LHC) and LPC as well as LHC and LCC had a strong positive correlation of 0.62 (*P* <0.01) and 0.61 (*P* <0.01) respectively. Lamb pastern circumference (LPC) and LCC were moderate positively correlated (0.59; *P* <0.01). Lastly the lamb chest circumference (LCC) and LSW parameters correlated moderate positively 0.53 (*P* <0.01) (Table 5).

Conclusion

Despite the Dorper ewes' more favorable pelvic area to lamb birth ratio they experienced significantly more lambing difficulty than the Dohne Merino ewes. This may be an indication that the Dorper has some form of conformational dysfunctionality resulting in difficult birth. The ewes that were born as a one of twins recorded larger pelvic areas in both breeds. This may indicate that by selecting for multiples the pelvic size in replacement ewes may increase over time. Lambing ease in the Dorper ewes was influenced the most by the lambs' head circumference, average birth time and birth weight of the ewe.

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Authors' Contributions

The trial was executed by JJ while PJF supervised.

Conflict of Interest Declaration

The authors declare there is no conflict of interest.

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