THE RELATIONSHIP BETWEEN PELVIC DIMENSIONS AND LINEAR BODY MEASUREMENTS IN DORPER SHEEP

By

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Abstract

Low lifetime rearing success and high perinatal mortality have been associated with small pelvic areas of ewes. Ewes with small pelvic areas are more prone to experience dystocia during parturition and high perinatal mortality. It would thus make sense to include pelvic area as criterion in selecting breeding animals (rams) in an attempt to assure bigger pelvic areas in the female progeny as the heritability of pelvic area ranges between 50-60%. The aims of this study were to develop two instruments to accurately measure the pelvic area and rump slope in small stock, to investigate the hindquarter dimensions and to quantify the relationship between a number of easy to measure external body measurements and pelvic dimensions of Dorper sheep. The pelvic meter developed was pre-tested on 90 sheep prior to slaughtering at an abattoir and shortly after slaughter. The correlation between the pre- and post- slaughter measurements was highly significant ($P < 0.05$; r = 0.85).

In this study 272 Dorper and White Dorper rams (5-7 months of age) participating in the Northern Cape Veldram project and 332 young Dorper and White Dorper ewes (±12 months of age) from three different breeders were measured. The inside pelvic area was measured trans-rectally. The rams' pelvic areas were measured five times transrectally, at 40 days intervals between the ages of 223 ± 41 and 385 ± 41 days of age. The height of the pelvis was obtained by measuring the distance between the dorsal *pubic tubercle* on the floor of the pelvis and the *sacrum* (spinal column) on the top. The width of the pelvis was measured as the widest distance, between the right and the left shafts of the *ilium* bones. The pelvic area was calculated using the π (PH/2)*(PW/2) formula. Other linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length) as well as body weight were taken. The rams' rump slope was measured in degrees with an instrument that was developed for this purpose, and the ewes' rump slope was visually scored on a scale from 1-5 with one being very flat and five being very droopy. The overall mean pelvic area of ewes 35.44 ± 4.89 cm^2 and those of the rams 28.22 ± 3.21 cm^2 differed with 7.22 cm^2. Stud ewes recorded significantly larger ($P < 0.05$) pelvic areas (37.38 ± 4.3 cm^2) than commercial ewes ($33.92 \pm 3.77 cm^2$). Results indicated that there are no significant correlations between pelvic dimensions and other body measurements considered in this study, indicating the need to measure pelvic area directly. Both the pelvic meter and rump slope meter, specially developed for this study, proved to be accurate and relatively practical to use in Dorper sheep.

Keywords: Pelvic meter, pelvic dimensions, linear body measurements, Dorper sheep

List of abbreviations

FPD	-	Feto-pelvic disproportion
PH	-	Pelvic height
PW	-	Pelvic width
BW	-	Body weight
SH	-	Shoulder height
CD	-	Chest depth
SW	-	Shoulder width
HW	-	Hindquarter width
RL	-	Rump length
PW	-	Pelvic width
PD	-	Pelvic height
PAπ	-	Pelvic area with π formula
OT	-	Outside thigh
IT	-	Inside thigh
CM	-	Conformation
S	-	Selection
CP	-	Chest projection
RS	-	Rump slope
BL	-	Body length
TC-PB	-	*Tuber cox*ae to the pin bone
PB-AB	-	Pin bone to the *acetabulum*
AB-TC	-	*Acetabulum* to the *tuber coxae*
HG	-	Heart girth
WBP	-	Width between pin bones
BCS	-	Body condition score
SC	-	Scrotal circumference
SI	-	Selection index
GC	-	Ground to *carpus*
GO	-	Ground to *olecranon*

Preface

The purpose of this study was to develop an instrument to measure the pelvic area of sheep; conduct a survey among Dorper farmers to investigate their opinion with regard to certain production and functional traits of the breed; investigate the pelvic area and hindquarter dimensions and to quantify the relationship between linear body measurements and pelvic dimensions in Dorper sheep.

This study is divided into a general introduction, including the objectives and hypotheses of the study, the literature overview, materials and methods, results and a general conclusion in an effort to create a cohesive unit.

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My parents and family for their continued support and belief in my abilities, and above all, I wish to thank God, for giving me life, strength, and the opportunity to research his creation.

I hereby declare that this thesis, submitted for the degree of Magister Technologiae, to be my own original work and that it has not been previously submitted by me or anyone else in respect of any qualification at any other institution.

I M van Rooyen

CHAPTER 1

GENERAL INTRODUCTION

1.1. Introduction

Low lifetime rearing and perinatal period (shortly before, during or within seven days after birth) mortality rates are often associated with small dimensions of pelvic opening of mature ewes (Haughey & Gray, 1982). Dystocia (birth difficulty) is common in sheep and causes the death of many lambs and ewes (Hartwig, 2002). Losses during the perinatal period may contribute up to 80% of total lamb deaths. Up to 60% of perinatal deaths could be attributed to stressful birth (Cloete *et al.,* 1998). Pelvic size heritability of 50-60 % were found in sheep (Kinne, 2002) and 36-92 % in beef bulls (Deutscher, 1991), therefore selecting rams with increased pelvic size should result in increased pelvic size in female progeny. This positive trait could be passed on to the entire herd by using appropriate sires.

Dystocia negatively influences the economics of an enterprise through lamb and ewe mortality, increased labour, veterinary costs, reduced subsequent reproductive performance and reduced milk production of the dam (Patterson & Herring, 1997). Furthermore, animals born during dystocia have lower weaning weights and are more susceptible to diseases (Walker *et al*., 1992). Although researchers agree that birth weight is the most important measurable trait affecting/causing dystocia, there is evidence that the size and shape of the pelvis also affect the ability of an animal to give birth (Patterson & Herring, 1997).

In particular, dystocia is related to an increase in the postpartum interval (days to first oestrus), an increase in non- reproductive days, a decrease in overall conception, a decrease in milk production and an increase in metritis and other uterine problems (Walker *et al*., 1992). Animals with extreme dystocia produce less milk than animals with no dystocia (Sieber *et al*., 1989).

A variety of factors contribute to both the cause and severity of dystocia. The relative degree to which any one of these factors contributes to dystocia is often mediated by other factors. These often-complex relationships make dystocia a particularly difficult problem to analyse and eliminate (Walker *et al*., 1992).

1.2. Problem identification

Over a period of time, the specific characteristics emphasised in selection in the Dorper breed, are mainly concerned the conformation of the animal. Most of these characteristics were aimed at the more symmetric build of the animal (Olivier, 2005). This caused certain body dimensions to change (eg. flat rump). It is not certain whether there are any relationships between body dimensions and pelvic dimensions in Dorper sheep.

In the female, pelvic dimensions play a significant role in dystocia. According to the literature, the primary cause of dystocia is attributed to disproportionately large fetus size or birth weight compared to the pelvic area (Troxel, 2008). However, the only way to record pelvic abnormality or size is by the actual measurement thereof.

The question that arises is whether the pelvic dimensions of rams have also changed and consequently affected lambing ease of their female offspring. This problem may be exacerbated by the fact that one ram may sire several offspring in his lifetime. It is also possible that the current dimensions of hindquarters and stance of legs contribute to the walking problems the breed experiences.

1.3. Rationale

Over the past decades Dorper sheep has shown that they are good converters of natural pastures into meat and that they have very good quality carcasses. These are some of the reasons why the Dorper is world- renowned. Over the past few years, the Dorper breed was subject to aggressive selection for mutton qualities. Animals were selected mainly on breed standards and their achievement in the show rings. In this field, symmetrical structure and muscling is important (Olivier, 2005). Growth rate in a natural production environment does not play a role in the judging of sheep, while reproduction, which is the most important economical factor, is not always considered. The question can be asked whether the breed has become too “beautiful” to adapt to the South African extensive production environment (Olivier, 2005). It is also debatable whether other characteristics like lambing and walking ability were affected by these conformation selection criteria.

According to Laster (1974), there were no external measurements which could be actually correlated to pelvic abnormality that accurately predicted pelvic area. He stated that pelvic area should be measured directly.

The direct measurement of the pelvic area of Dorper rams can therefore be an effective tool in identifying rams that are either superior or inferior regarding this highly heritable (50-60%) trait (Deutscher, 1975). Heritability of 50-60 % was found in sheep (Kinne, 2002) and 36-92 % in beef bulls (Deutscher, 1991). Selecting rams with increased pelvic size should result in increased pelvic size in their female progeny, resulting in decreased dystocia and less perinatal mortality. However, the measuring of the pelvic area is an operation that requires skill and suitable equipment - something that is not always available to the farmer. In this study, the relationship between linear body measurements and conformation traits (which are easier for the breeder to evaluate) and pelvic area will also be investigated.

1.4. Objectives of the study

- To develop an instrument to measure the pelvic area of sheep.
- To conduct a survey among Dorper farmers to determine their opinion with regard to certain production and functional traits of the breed.
- To investigate the pelvic area and hindquarter dimensions.
- To quantify the relationship between linear body measurements and pelvic dimensions in Dorper sheep.

1.5. Research hypotheses

- There is a significant correlation between certain linear body measurements and pelvic measurements.
- Pelvic growth is linear and stabilizes at puberty.
- There is a considerable variation in pelvic dimensions among Dorper sheep of the same age and weight.

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CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Dystocia occurs when there is a failure in one or more of the three main components of birth: expulsive force, birth canal adequacy and fetal size or position (Mee, 2008). Deutscher (1991) indicated that the major cause of dystocia is a disproportion between the offspring's birth weight and the dam's pelvic area. This finding is also supported by Cook *et al*., 1993 & Troxel, 2008. Smith (2005), (found reported in the literature) that 13 296 calvings had 41 % of mortalities occurring with first calf heifers; 57.6 % of the deaths occurred within 24 hours of birth and calving difficulty accounted for 37.9 % of the deaths. Studies indicated that calf death due to dystocia accounts for the single largest prenatal and postnatal loss in the first 96 hours after birth (Patterson & Herring, 1997). Excessive birth weight is the primary cause of dystocia (Bellows *et al*., 1971). According to Cook *et al*. (1993), the selection for sires based on birth weight estimated progeny difference is a much more effective tool than selection of replacement heifers. Selection for sires with low birth weight should reduce calving difficulty and hence calf losses, (Cook *et al*., 1993). These calves generally also grow more slowly than a calf with a heavier birth weight (Cook *et al*., 1993 and Van Zyl, 2011). 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.

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.

2.2. Relationship of body measurements

Body size and body shape of sheep can be described by using measurements and visual assessments of size and shape. These relate to the functioning of the individual and are of paramount importance in livestock production. Therefore, constant checks on the relationships between body measurements and performance traits are vital in selection programmes (Maiwashe, 2000). Body weight is an important indicator of growth, but fails to indicate the composition of the animal. Therefore measurements of the animal's frame can be considered indirect indicators in determining meat leanness (Greyling & Taylor, 1999). Body measurement is most commonly used to evaluate growth (Fourie *et al.,* 2002). According to Greyling & Taylor (1999), highly significant correlations (P <0.01) were obtained for body length and shoulder height (r = 0.86), shoulder width (r = 0.8), body weight (r = 0.92) and scrotal circumference (r = 0.86). Most body measurements are associated with bone growth (Greyling & Taylor, 1999). Some parameters like shoulder height and shoulder width grow at a slower rate than body length, while these linear body measurements are also highly correlated with live weight (Greyling & Taylor, 1999). Van Donkersgoed *et al*., (1990) stated that measuring the pelvic area of the dam to predict dystocia has once again become popular as a tool in selecting replacement heifers, even though pelvic area alone has been shown to explain only a small proportion of the variability in dystocia. Heifers with calving difficulty had significantly (P = 0.03) smaller pelvic area measurements, when examined during pregnancy, than those without calving difficulty (Van Donkersgoed *et al*. 1990). He also found that heifers with calving difficulty had significantly (P <0.0001) heavier calves at birth than those without calving difficulty.

2.3. Factors that can play a role in dystocia of sheep

2.3.1. Age of dam

High birth weights have been associated with increased dystocia in ewes bearing single lambs. Young ewes are more susceptible to lambing problems than mature ewes that have lambed previously (Anderson, 1992 and Hartwig, 2002).

2.3.2. Lamb birth weight

According to Smith (1977), the breed, year, type of birth, ewe age and sex of the lamb influence the birth weight of purebred lambs. According to MacNeil *et al*. (1998), simultaneously selecting for low birth weight and high genetic potential for subsequent growth, seems to be a valid management strategy that will result in genetically improved calving ability in cattle and should also apply in sheep. This is in contradiction with Van Zyl, (2011) who found that selecting for lower birth weight to decrease dystocia can result in lower afterbirth growth in cattle.

2.3.3. Dam's pelvic area

According to Fogarty & Thompson (1973), dystocia in Dorset Horn ewes tended to be associated with smaller pelvic areas. They also found that general measurements in the pelvic region were closely correlated with transverse diameter of the pelvis, but not with pelvic area or conjugate diameter. Birth weight, the size of the pelvic area of the dam, and the interrelationship between these two factors are determinants of dystocia (Merck & Co., 2008: Online). According to Briedenhann (2010), there are two important factors to consider for calving ease. The first is the size of the pelvis opening (the bigger the better) and the second is the anatomy of the pelvis (abnormalities in the pelvis can cause dystocia).

2.3.4. Gestation length

Normal gestation length for sheep is between 144 and 152 days (Cole & Garrett, 1980). According to Echternkamp & Gregory (1999), factors linked to gestation length (period of pregnancy) were retained placenta, age of the dam, and sex of the lamb (Anderson, 1992).

2.3.5. Body condition of dam

Body condition is a very important factor when considering ease of lambing.
The five condition scores as presented by Thompson & Meyer, (1994):

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.

Over fat animals are more prone to dystocia (Thompson & Meyer, 1994).

2.3.6. Twins or single lambs

Increasing the incidence of twins is a method to increase productivity (Echternkamp & Gregory, 1999).

2.3.7. Position and presentation of the lamb in the uterus

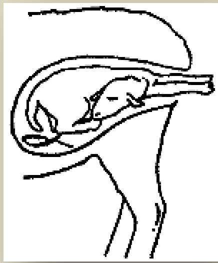
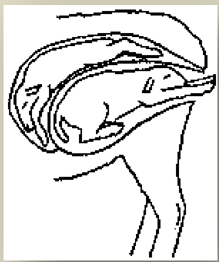
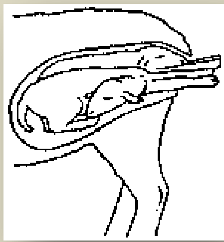
 Backwards presentation (also normal).	 Breech presentation (tail only).
 One leg back.	 Both legs back.
 Elbow lock.	 Head back.
 Twins - front and back.	 Twins – four legs.

Figure 1: A set of figures showing different possible abnormal presentations of the lamb(s) in a ewe (Martin, 2008).

Abnormal presentations cause some difficulties in lambing. Positioning in a normal presentation: 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. 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 familiar with large animal situations may be needed (Anderson, 1992 and Wilson & Rossi, 2006).

2.3.8. Sire selection

Some producers blame dystocia on the breed of the sire because of heavy birth weight and large frame size. There are sires within each breed that can cause dystocia when mated with certain females. Therefore, the sire for each female should be well chosen. This will help eliminate mating large-framed sires to small-framed nulipare animals. Sires that produce low birth weight offspring when mating nulipare animals, reduce possible dystocia (Anderson, 1992, and Wilson & Rossi, 2006), but according to Van Zyl (2011) it will result in lower growth rate after birth. As animals mature and grow in body size, they can be mated with larger-framed sires, since they will be more capable of delivering larger foetuses. Although many producers evaluate breed, structure, frame score and genetics when selecting sires, 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 (Anderson, 1992 and Wilson & Rossi, 2006).

2.3.9. Season of birth

Temperature has been shown to have a significant impact on birth weight. Although using sires with low birth weight may reduce dystocia considerably, environmental factors are responsible for approximately 55 % of dystocia.

Birth weights can vary significantly from year to year even with similar genetics and management (Anderson, 1992 and Wilson & Rossi, 2006).

2.3.10. Feeding

During pregnancy, high feeding levels had no significant impact on birth weight or dystocia. Reduced feeding levels, however, can actually cause weight loss, decreased milk production, increased incidence of scours and, most importantly, decreased pregnancy rate. Growing animals on a low nutrient diet have clearly resulted in an increase in dystocia. This is primarily due to abnormal skeletal growth and therefore smaller pelvic areas (Anderson, 1992 and Wilson & Rossi, 2006). Overfeeding animals causes internal fat deposits which obstruct the pelvic canal. In a beef cattle operation, overfeeding is seldom a major contributing factor to dystocia. All managers however, must maintain a balance between achieving maximum frame growth without allowing excessive fat deposits. Fat animals will have high incidences of dystocia just as severely as underdeveloped animals (Wilson & Rossi, 2006)

2.3.11. Double muscling

Double muscling is associated with reduced fertility, abnormal structure of the body and respiratory and cardiovascular disadvantages (Olivier, 2005). Currently, some Dorpers have very flat rumps with excessive muscling in the hindquarters when compared with other sheep breeds. The pregnancy period of double muscled cows is longer, resulting in higher birth weight and the chance for dystocia increases. According to Olivier (2005), birth of double muscled Belgian Blue cows is only possible through a caesarean operation. The reason for this is most likely too heavy birth mass and relativly small pelvic structure. There are different types of over muscling in sheep. The Belgian Texel sheep is an example of double muscling that compares with that of cattle. In cattle, the absence of the protein myostatin (a growth factor that limits muscle tissue growth) is associated with extreme muscle growth. Over years, that specific breed has been selected for extreme muscling and producing a large percentage of expensive cuts with less fat (Olivier, 2005).

Tests show that the dressing percentage of double muscle sheep was as much as seven percent higher than normal sheep. Because of accentuation of muscling, the Dorper breed has lost its growth potential and the weight of yearlings has dropped by 1.3 kg per year. This selection objective of over muscling has lead to lower fertility and lower general health (Olivier, 2005).

In 1983, a Dorset Horn ram in Oklahoma with huge muscle development in his hindquarters was mated with “normal” ewes. Some of the offspring also showed this type of muscling. In reproduction this trait is unique and it was the first time that polar overdominance could be examined. This means that the gene would only be present in lambs that have received the specific gene from their father. This gene is known as the Callipyge gene. One characteristic of this gene is that sheep only start to show over muscling three weeks after birth, which means no dystocia is present due to over muscling at birth. 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 outcome percentage with more muscle and less fat. This shows that phenotypic selection for muscling is possible. There are also some serious consequences that cannot be ignored. Selection for muscle development in the Dorper breed cannot be applied without decreasing growth rate, reproduction rate and general health (Jackson *et al*., 1997; Olivier, 2005).

In the SA Mutton Merino Cloete *et al.* (1998) found that the slope of the rump (subjectively scored) was positively correlated to pelvic area, in other words the flatter the rump appeared, the smaller the pelvic area would be. Similar results were obtained in dairy cattle, but not in beef cattle. According to several studies, pelvic area is playing a significant role in dystocia and difficult birth. It appears that 80% of deaths occur within seven days after birth. Of this 80%, 60% can be related to dystocia (Cloete *et al.,* 1998).

According to research at the South Dakota State University, the incidence of calving difficulty is more than twice as high in heifers with below average pelvic development, compared with animals with above average development.

In an Oklahoma study, 85% of heifers with a small pelvis experienced calving difficulty, while 31% of heifers with a large pelvis had little difficulty with calving (Anderson, 1992). This study reveals that not only the size of the pelvis plays a role, with above average pelvic sized heifers' also experiencing dystocia.

2.3.12. Hormones

Testosterone appears to be the principal testicular hormone for superior performance and preferred carcass characteristics in young rams (Schanbacher *et al*., 1980). According to Echternkamp & Gregory (1999), the increase of fetal malpresentation of twins may result from higher concentrations of progesterone and estradiol found in females gestating multiple foetuses. Treatment with progesterone or estrogen to reduce retained placentas; results in increased dystocia, and abnormal fetal presentation.

2.3.13. Other factors that also have an influence on dystocia

Age of the ram, sex of lamb, size of dam, breed and genotype of sire, breed and genotype of dam, nutrition of dam, geographic conditions and season can also promote dystocia (Anderson, 1992).

2.4. Importance of Pelvic measurements

According to Anderson & Bullock (1994), and Patterson & Herring (1997), a difference in pelvic size is usually attributed to a difference in pelvic height. Green *et al.* (1986) found a 0.61 genetic correlation between male and female pelvic areas. The heritability of pelvic area is between 0.36 to 0.68, while the heritability of pelvis height is greater than the heritability of the pelvis width and pelvic area is more heritable than height or width (Boyles, 2000; Kinne, 2002). Some research has estimated the heritability of pelvic area to range from 36 % to 92 % with an average of 61 %, with these values indicating that pelvic area heritability may be higher than 45 % for calf birth weight (Deutscher, 1991). Pelvic size can be readily transmitted from the sire to the resulting progeny, according to a Colorado study that found a

0.60 genetic correlation, indicating that the selection for large pelvic size in bulls should result in increased pelvic size of the female offspring (Deutscher, 1991). Green *et al.* (1986) also reported a genetic correlation of 0.61 between male and female pelvic areas. According to Laster (1974), cow weight was the largest source of variation associated with pelvic area, but breed adjusted for cow weight, had a significant (*P* <0.01) effect on pelvic area. Smith (2005) alleges that pelvic measurements can be successfully used to identify abnormally small or abnormally shaped pelvises.

2.5. Factors that have an influence on dystocia can be grouped into two classifications:

1. Factors affecting size and shape of the lamb.
2. Factors affecting the ability of the dam to give birth (Anderson, 1992).

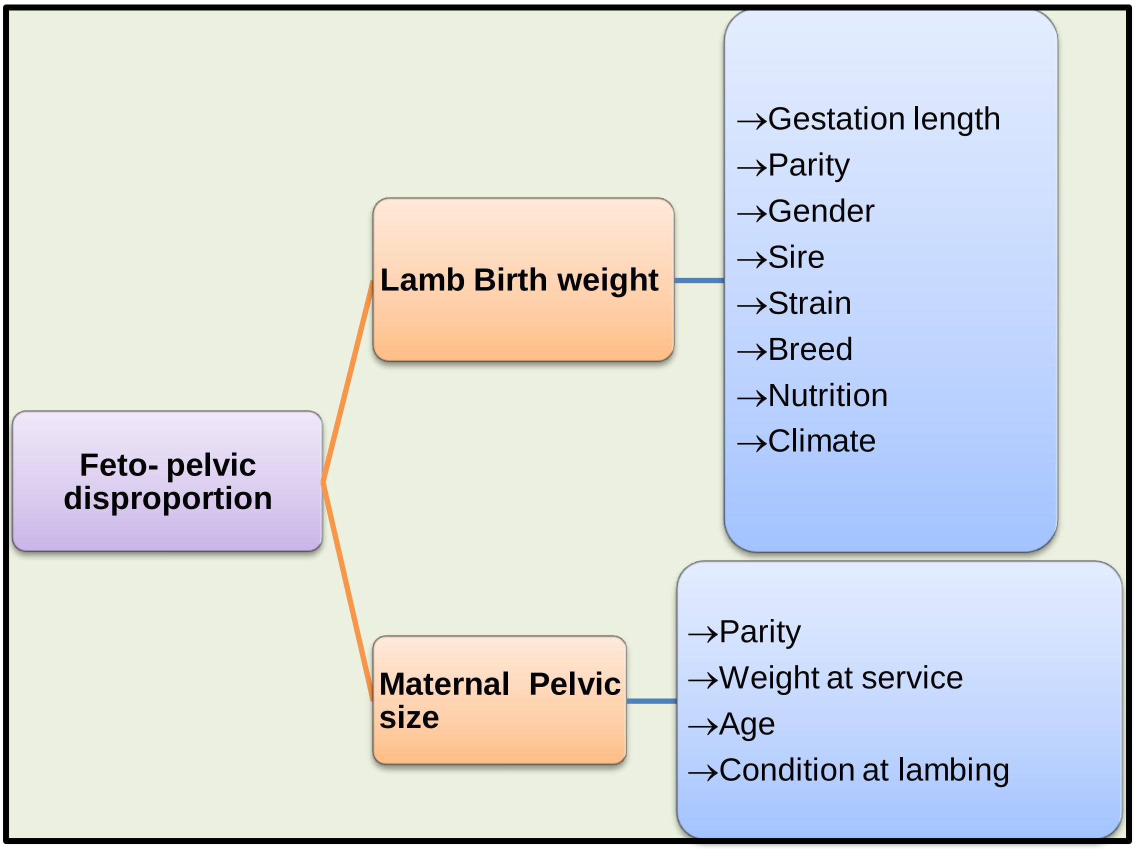


Figure 2: An illustration of intermediate and ultimate cause of dystocia due to feto-pelvic disproportion (FPD) (Adapted from Mee, 2008).

Feto-pelvic disproportion (FPD) is any clinically mismatch between the size or shape of the presenting part of the fetus and the size and shape of the maternal soft tissue. According to Kilgour & Haughey (1993), feto- pelvic disproportion is undisputedly a major cause of death during parturition as a result of severe asphyxia associated with prolonged parturition and dystocia; it may also be a factor in neonatal lamb death due to pathophysiological handicaps imposed on the newborn by asphyxic birth injury to the central nervous system. 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). Cloete *et al*. (1998) reported that FPD was a reason for assistance in more than 50 % of SA Mutton Merino births where dystocia of maternal origin was recorded. Cloete *et al*. (1998) also found this condition absent in Dormers and stated that breed differences were being significant (P <0.01).

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 (McSporran & Fielden, 1979, Anderson, 1992 and Patterson & Herring, 1997).

McSporran & Fielden, (1979) studied mature Romney ewes, with different histories of lambing performance, which were x-rayed to obtain measurements of pelvic dimensions. The ewes in group one had all been assisted to lamb at least once, where the ewes of groups two and three had no history of dystocia. Group two was selected from a commercial flock and the group three ewes from a closed flock that had been unshepherded at lambing for approximately 40 years.

Results indicated that the pelvic openings differ between groups in such a manner that groups two and three had larger pelvic areas than group one ewes. Size of the pelvic opening in relation to birth weight of the lambs also differed between groups, with group three ewes having the largest and group one the smallest pelvic openings. Significant correlations were recorded between a number of internal and external pelvic measurements, but were not considered high enough to be of use in predicting internal pelvic dimensions from external measurements (McSporran & Fielden, 1979).

Heifers with increased body frames usually have larger pelvic openings, but also tend to have heavier calves at birth. This means that selection for cow size alone will be ineffective to prevent dystocia, which leaves the option of measuring the animal internally (Patterson & Herring, 1997).

Data from pure bred and crossbred lambs were analysed to determine the focus that should be given to dystocia and lamb survival rates in selection programs to determine sire breeds (Smith, 1977). Both dystocia and lamb mortality were quadratically related to birth weight. Dystocia was minimal (9-15%) at birth weights of about 3.5 kg, whereas mortality was minimal (26-30%) at about 5.5 kg. Dystocia increased lamb mortality by 8.6% in pure bred and 4.8% in crossbred lambs. Single-born lambs were heavier at birth and had fewer deaths than multiple born lambs. Single born lambs also had more dystocia than multiple born lambs (Smith, 1977). Both dystocia and lamb mortality were quadratically related (P <0.01) to birth weight (Smith, 1977).

A study by Laster (1974) stated that pelvic size and other physical anatomical measurements of cows were associated with dystocia in Hereford and Angus cows. His results indicated that larger cows had larger pelvic openings and that the tendency for larger cows to have larger pelvic openings is quite similar in different breed groups. The relationship of dystocia to pelvic size and other measurements describing cow size, condition and anatomy were too low to accurately predict dystocia in beef cattle.

It should not be assumed that all large-framed females have large pelvic areas or that all small frame females have small pelvic areas. Jerseys are small cattle that have very large pelvises, compared with other breeds of similar size (Laster, 1974).

Low life rearing efficiency, high levels of dystocia and parental mortality have been associated with small dimensions of the pelvic inlet and mature ewes (Haughey & Gray, 1982). 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 program to reduce dystocia and perinatal instability in lambs and ewes (Troxel, 2008).

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CHAPTER 3

A questionnaire based survey: Farmers' opinion of the Dorper breed with regard to certain productive and functional traits.

3.1. Introduction

Constant checks on relationships between body measurements and performance traits are vital in selection programmes (Maiwashe, 2000). According to Fourie *at al*. (2002), the Dorper breed is the second largest sheep breed in South Africa, and therefore has a major impact on slaughter lamb production in the country.

The objective of this chapter was to obtain the opinions of stud as well as commercial Dorper farmers, regarding production and functional traits of the breed. Firstly, the procedure will be discussed and secondly the results. Concluding remarks will be made in the summary.

3.2. Materials and Methods

3.2.1. Research design

A questionnaire that contains both structured and open-ended questions was designed for specific use among stud as well as commercial Dorper farmers (Addendum B). An existing questionnaire of the Dorper Breeders' society was used as a guideline in compiling the questionnaire. The wording has been carefully selected, taking care to exclude ambiguities. The spaces provided on the questionnaire for recording information were arranged appropriately so that the data would be readily accessible for analysis.

A thoughtful conversation with the farmers (referred to in this study as respondents) was the first step in obtaining this accurate information about the functionality of the Dorper breed. In the course of the communication, it was imperative to avoid judgemental behaviour, disrespectful comments and to conduct interviews in a tolerant and understanding way.

3.2.2. Sampling

A stratified random sample was used. Most of the Dorpers in the country are found in the more arid western part of the country, therefore the Upington national sale was included in the sample as it is by far the largest sale in the country with buyers and sellers from all over the country and Namibia. Secondly the Griekwastad veldram sale is also the oldest and largest sale of its kind in the country.

A total of 66 respondents of seven provinces completed questionnaires (questionnaires were completed at one production sale, one veldram sale and one national sale to ensure that the breeders and farmers of all the provinces are represented).

Table 1: The sample population of Dorper farmers targeted at three different auctions.

Dorper breeders and commercial farmers attending the auctions	Number of breeders /farmers who served as respondents
Upington National sale	33
Griekwastad veldram sale	11
BS Grobbelaar production sale	22
Total	**66**

3.3. Results

Most of the respondents farmed with Dorpers for longer than ten years and more than 56% have stud flocks. The respondents' opinions were that the Dorper's hardiness and fertility (lambs marketed per year) have decreased slightly over the past five years, as can be seen in Figures 3 & 4.

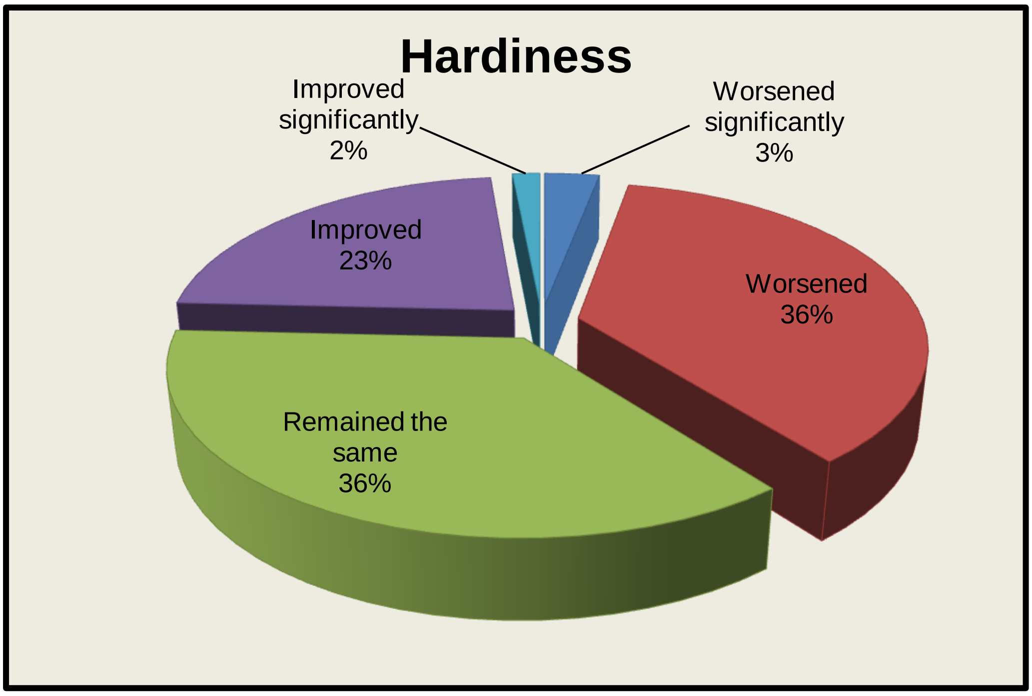

Figure 3: Farmers' opinion about the hardiness of the Dorper over the past five years

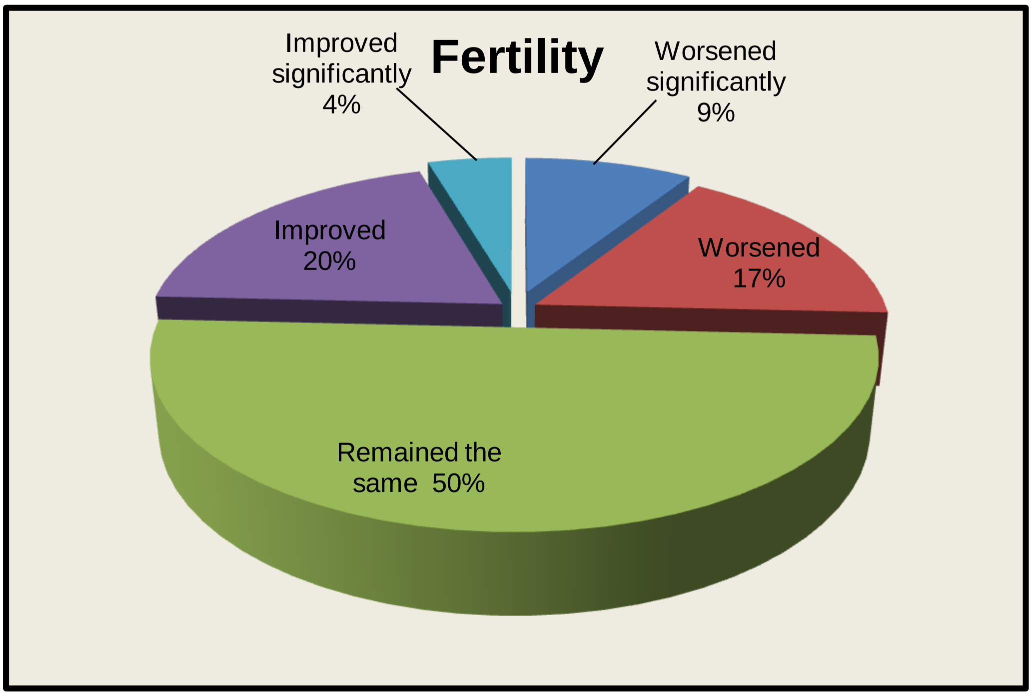

Figure 4: Farmers' opinion about the fertility of the Dorper over the past five years

There were varying opinions among the respondents about ewes that suffer from dystocia. According to Figure 5, 36% of the respondents was of the opinion that there was an increase in dystocia among ewes, 38% of the respondents was of the opinion that the percentage has stayed the same, and 26% felt that there was a decrease in dystocia among Dorper ewes, but the common feeling was that there is a trend to more difficulty in birth among Dorper ewes.

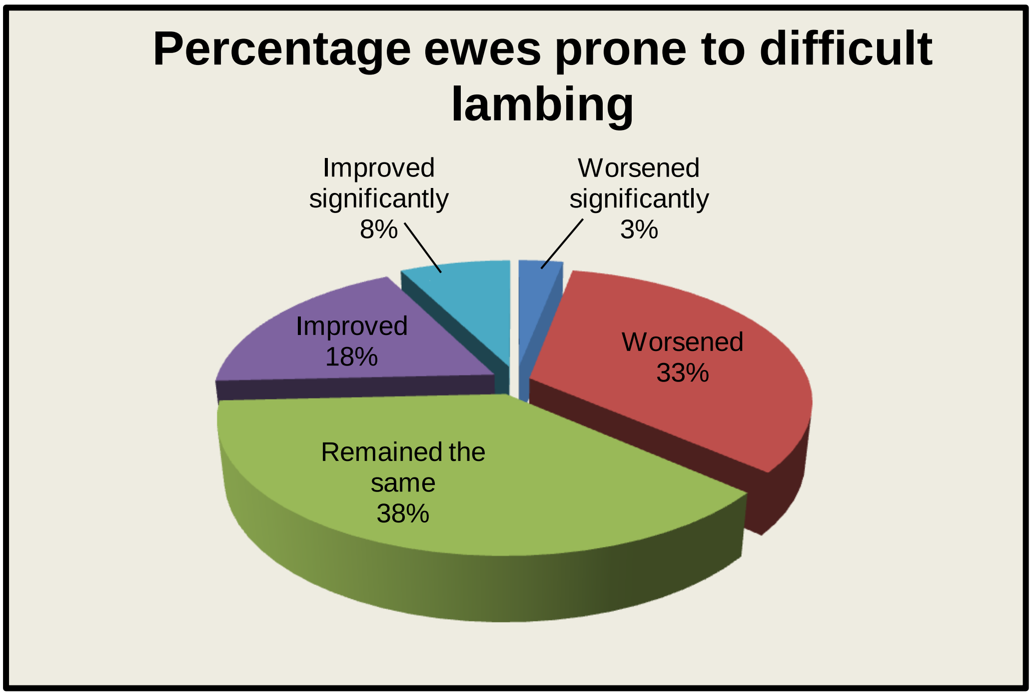

Figure 5: Farmers' opinion of the percentage of Dorper ewes with dystocia

Young ewes are mated at an average age of 10 months, at an average weight of 43kg. Most respondents mate their young ewes with Dorper rams, but there are some farmers (10.6%) that use other breeds like the Damara, Persian and Van Rooy.

There were varying opinions among the respondents about venereal diseases. Of these, the majority of 59% was of the opinion that Dorpers have no venereal diseases, 13.6% responded that there is a decrease in venereal disease, 15.2% thought the incidence of venereal diseases was unchanged and 12% stated that there was an increase in venereal diseases.

According to the respondents, the average daily gain, dressing percentage, grading and carcass weight increased slightly, while the walking ability worsened.

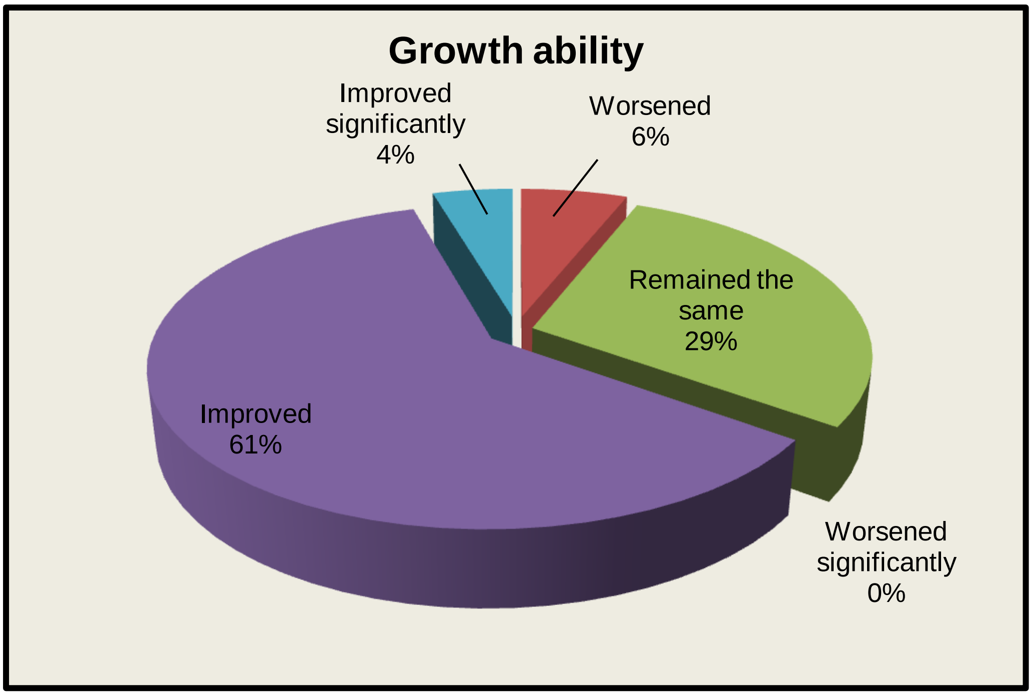

Figure 6: Farmers' opinion of the growth ability of the Dorper

The stud breeders as well as the commercial farmers at the Griekwastad Veldram auction indicated that they are not interested in buying rams raised under feedlot conditions. Farmers at this auction have also indicated that they want the performance figures of the ram's dam as well as the performance figures and the growth ability of the ram's sire.

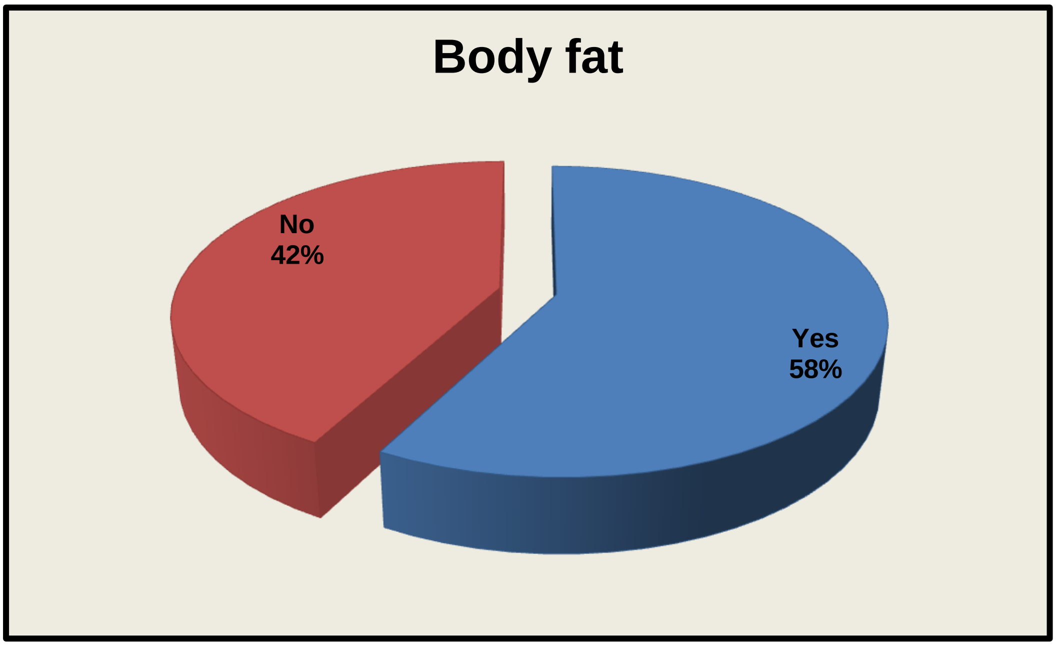

Figure 7: Farmers' assesment of the natural body fat of the Dorper.

Fifty eight percent of the respondents indicated that the breed has sufficent body fat while 42% was of the opinion that the Dorper is lacking in natural body fat. There are no significant difference in the growth ability of animals with hair, a mixture of hair and wool, and those with only wool (Snyman & Olivier, 2002).

3.4. Conclusion

It was striking that the stud farmers in general valued the characteristics more positively than the commercial farmers did. From the discussions with farmers it was evident that some farmers have clear breeding objectives; such farmers were in general more satisfied with the breed's current performance. It is however alarming that 36% of the respondents stated that there was an increase in dystocia among Dorper ewes. This serves as further motivation for this study.

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CHAPTER 4

The relationship between pelvic dimensions and linear body measurements in Dorper ewes

Abstract

Low lifetime rearing success and high perinatal mortality have been associated with small pelvic areas of ewes. It would thus make sense to include pelvic area as criterion in selecting breeding ewes, however measuring *in vivo* poses some challenges. The aim of this study was to investigate the pelvic areas and hindquarter dimensions in Dorper ewes and evaluate if the selection according to breed standards resulted in indirect selection for different pelvic areas in ewes, as well as to quantify its relationship with a number of easy to measure external linear body measurements. In this study, 332 young Dorper ewes (± 12 months old; 48.0 ± 5.75 kg) from three different stud breeders were measured. All the ewes were managed under extensive conditions, supplemented only with a salt lick. The ewes' pelvises were measured trans-rectally with the aid of a specially designed pelvic meter for sheep. The pelvis height was obtained by measuring the distance between the *dorsal pubic tubercle* on the floor of the pelvis and the *sacrum* (spinal column) on the top. The width of the pelvis was measured as the widest distance, between the right and the left shafts of the *ilium* bones. The pelvic area was calculated using the π (PH/2)*(PW/2) formula. Other linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length) as well as body weight were taken. The slope of the rump was visually scored on a scale from 1-5 with one being very flat and five being very droopy. All ewes were inspected by senior Dorper inspectors and classified according to breed standards as stud (Types 4 and 5) or commercial (Types 2 and 3) or culled (Type 1). The overall mean pelvic area of yearling Dorper ewes was 35.44 ± 4.89 cm^2. Stud ewes recorded significantly higher (P <0.05) pelvic areas (37.38 ± 4.3 cm^2) than commercial ewes (33.92 ± 3.77 cm^2). Results also indicate no significant correlations between the pelvic dimensions and all other body measurements considered in this study, indicating the need to measure the pelvic area of ewes directly. The pelvic meter,

specially developed for this study, proved to be a useful tool and relatively practical to use in Dorper ewes.

Keywords: Pelvic meter, pelvic dimensions, linear body measurements, Dorper ewes

4.1. Introduction

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). 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). According to Sieber *et al.* (1989), animals that experienced extreme dystocia, produced less milk than animals that experienced no dystocia. Kilgour & Haughey (1993), reported that a major cause of reproductive wastage in sheep is perinatal mortality of lambs. Small pelvic dimensions in ewes have proven to be associated with high levels of dystocia and poor lifetime rearing performance (Kilgour *et al.*, 1993). Dystocia is common in sheep and causes the death of many lambs and ewes (Hartwig, 2002). It would thus make sense to include pelvic area as one of the criterion 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.

Body size and body shape can be described by measurements and visual assessment. How these measurements of size and shape relate to the functioning of the individual is of paramount importance to livestock production. Therefore, constant checks on the relationships between body measurements and performance traits are vital in selection programs (Maiwashe, 2000). The aim of this study was to investigate and quantify the correlations between pelvic measurements (height, width and area) and other easier to measure external linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length, etc) in Dorper ewes as well as to investigate whether the selection according to breed standards resulted in indirect selection for different pelvic areas in ewes.

4.2. Material and Methods

4.2.1. Animals

Three hundred and thirty-two Dorper ewes (Dorpers & White Dorpers ± 12 months old; 48.0 ± 5.75 kg) from three different breeders were measured. All the ewes were managed extensively on the veld during the time of the trial and received only a salt lick as supplementation.

4.2.2. Environment

Central Northern Cape (Prieska, Marydale and Kenhardt areas)

According to Acocks (1988) this vegetation type occupies the valley of the Orange River to a point approximately 150 km east of the Vaal River, as well as part of Namaqualand. It has a low average rainfall of 50-300 mm per annum, raining mostly in the summer in the eastern parts and in the winter in the western parts. The vegetation becomes more succulent towards the western parts. The presence of *Aloe dichotoma* is typical of the vegetation of this region. Other bushveld trees and shrubs, like *Acacia* species (*A. mellifera* subsp. *detinens, A. karroo, A. erioloba*) are prominent in this region. There is also a great variety of grasses.

4.2.3. Instrument

A pelvic meter for sheep was developed in collaboration with the Science Park of the CUT (Central University of Technology, Free State). The pelvic meter developed was pre-tested at the Bloemfontein abattoir on 90 randomly selected sheep prior to slaughtering and shortly after slaughtering. The correlation between the pre- and post- slaughter measurements was highly significant (height 0.80 $P < 0.05$: width 0.87 $P < 0.05$; area 0.85; $P < 0.05$). The pelvic meter is presented in Figure 8.

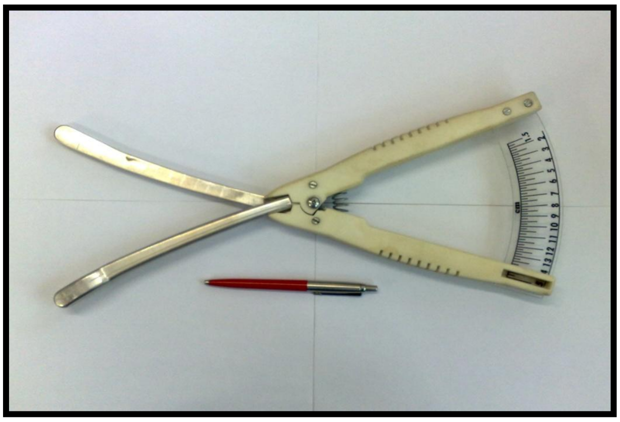

Figure 8: Pelvic meter used to measure the pelvic dimensions of ewes.

4.3. Measurements

4.3.1. Pelvic measurements

Figure 9 shows 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; Van Zyl, 2008).

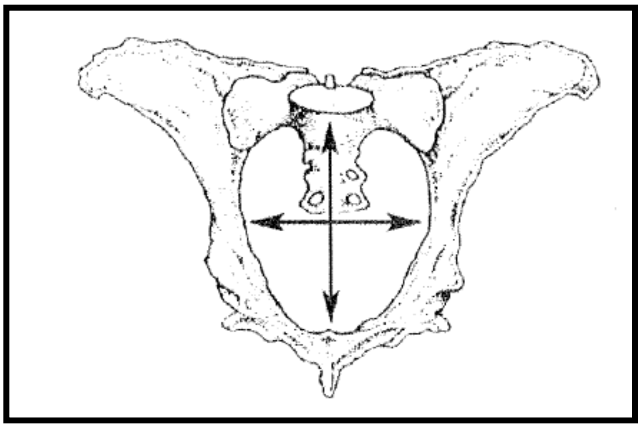

Figure 9: Measurement areas for the pelvic measurements (Anderson & Bullock, 1994).

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 were then removed from the rectum if necessary and the instrument was carefully placed into the rectum (Deutscher, 1975, Van Zyl, 2008).

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 9). 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 9). 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; Van Zyl, 2008). 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 Zyl, 2008). 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). Pelvic area is a criterion which can be used to cull or keep ewes or rams (Van Zyl, 2008).

4.3.2. Body measurements:

The following data were recorded:

- Body weight (kg)
- Shoulder height (cm), measured vertically from the *thoracic vertebrae* to the ground (Fourie *et al*., 2002).
- Chest depth was measured from the *spianus* to the *xyfoid* process of the sternum (Fourie *et al*., 2002).
- Forequarter width was measured from the left *scapula* to the right *scapula*.
- The hindquarter width was measured between the left thurl to the right thurl.
- Distance from the *tuber coxae* to the pin bone (rump length).

4.3.3. Conformation traits (were assessed subjectively by experienced judges):

- Outside thigh (on a 5 point scale with 1 being poorly muscled and 5 very well muscled).
- Inside thigh (on a 5 point scale with 1 being poorly muscled and 5 very well muscled).
- Conformation (on a 5 point scale with 1 being poor conformation and 5 very good conformation).
- Selection (according to the breed standards with 1 being a cull, 2 being 2nd selection, 3 commercial, 4 being Type 4 stud and 5 being Type 5 stud).
- Chest projection (on a 5 point scale where 1 is very flat and 5 are very prominent).
- Rump slope (Visually on a scale of 1 – 5 with 1 being very flat and 5 being very droopy).

4.4. Data analysis

Analyses of variance were conducted to determine the relationship between parameters. Data was analysed using the General Linear Model procedures of SAS (SAS, 1989). Product moment correlations between the variables were calculated. A stepwise regression was carried out to determine the individual influence of body measurements on pelvic area. An F to enter the level of 0.10 was used to determine the significance of the partial contribution of each effect. Pelvic area was included as a covariate.

4.5. Results and Discussion

The mean difference between pelvic height and pelvic width is very similar and pelvic area recorded a small variance among yearling ewes (Table 2). The difference in pelvic size is usually attributed to the difference in pelvic height (Anderson & Bullock, 1994 and Patterson & Herring, 1997). Heritability of pelvic height is greater than that of pelvic width. Pelvic area is more heritable than pelvic width or pelvic height (Boyles, 2000).

Table 2: Mean and standard deviation (s.d.) of parameters measured during the trial of yearling Dorper ewes.

Parameter	**Ewes** **Mean ± s.d.**
Body weight (kg)	48.0 ± 5.75
Shoulder height (cm)	60.9 ± 2.43
Chest depth (cm)	29.1 ± 1.33
Shoulder width (cm)	21.5 ± 1.22
Hindquarter width (cm)	18.3 ± 1.02
Rump length (cm)	20.4 ± 1.22
Pelvic width (cm)	6.6 ± 0.45
Pelvic height (cm)	6.9 ± 0.46
Pelvic area (cm^2)	35.55 ± 4.89
Outside thigh	3.5 ± 0.67
Inside thigh	3.7 ± 0.63
Conformation	3.5 ± 0.64
Selection	3.6 ± 0.77
Chest projection	3.7 ± 0.47
Rump slope (^{o})	3.6 ± 0.56

Table 2 gives an overview of the means of some of the body dimensions of Dorper ewes.

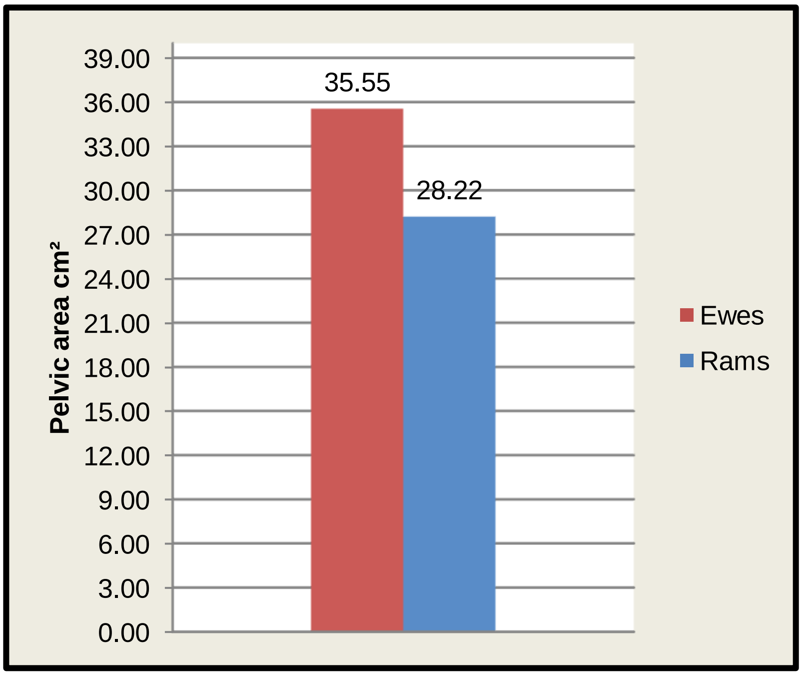

Figure 10: Difference in averages of pelvic area between Dorper ewes and Dorper rams.

From Figure 10 it is evident that the pelvic area of ewes (33.55 ± 4.89 cm^2) is 5.33 cm^2 bigger (P <0.05) than that of rams (28.22 ± 3.21cm^2) of the same age. Green *et al*. (1986) reported a 61 % genetic correlation between male and female pelvic area in cattle.

Table 3: Phenotypic correlations between parameters in Dorper ewes.

Para-meter	BW	SH	CD	SW	HW	RL	PW	PH	PA	OT	IT	CM	S	CP	RS
BW															
SH	0.490														
CD	0.668	0.526													
SW	0.644	0.280	0.489												
HW	0.583	0.424	0.530	0.418											
RL	0.580	0.468	0.478	0.397	0.498										
PW	0.256	0.120	0.239	0.105	0.298	0.037									
PH	0.239	0.089	0.243	0.096	0.240	0.034	0.771								
PA	0.241	0.104	0.255	0.123	0.248	0.045	0.941	0.842							
OT	0.282	-0.181	0.150	0.263	0.133	-0.085	0.243	0.263	0.259						
IT	0.312	-0.136	0.065	0.239	0.147	-0.015	0.104	0.157	0.114	0.666					
CM	0.320	-0.142	0.084	0.265	0.183	-0.043	0.269	0.265	0.276	0.642	0.614				
S	0.355	-0.157	0.103	0.297	0.210	0.009	0.263	0.252	0.267	0.677	0.628	0.929			
CP	-0.110	-0.106	-0.076	-0.042	-0.094	-0.168	0.109	0.154	0.161	0.127	0.014	0.205	0.204		
RS	0.177	-0.051	0.062	0.046	0.095	0.001	0.204	0.266	0.256	0.377	0.317	0.439	0.465	0.199	

Body weight (BW), Shoulder height (SH), Chest depth (CD), Shoulder width (SW), Hindquarter width (HW), Rump length (RL), Pelvic width (PW), Pelvic height (PH), Pelvic area (PA), Outside thigh (OT), Inside thigh (IT), Conformation (CM), Selection (S), Chest projection (CP), Rump slope (RS).

Table 3 depicts the correlation between most variables considered in this study. As can be seen in Table 3 there is a medium correlation of 0.67 (*P* <0.001) between body weight and chest depth, as well as a 0.66 (*P* <0.001) correlation between body weight and shoulder width. Shoulder height showed a negative correlation of -0.18 (*P* <0.001) and -0.14 (*P* <0.001) with both outside thigh and inside thigh respectively, which is an indication that the bigger animals carry less visible muscling in the hindquarters. It is also evident that conformation (-0.14, *P* <0.001) and selection (-0.16, *P* <0.001) are also negatively correlated with shoulder height, which may be an indication that the breed standard is giving preference to animals that are shorter on their legs. In general, all pelvic measurements recorded high correlations between each other and very low correlations with all other body measurements considered in this study. The correlation between pelvic width and pelvic height is also high (0.77, *P* <0.001). Smith (2005) stated that the growth of pelvic height and pelvic width differs between different frame sizes of beef heifers. The high correlation between pelvic width and pelvic area (0.94, *P* <0.001), as well as between pelvic height and pelvic area (0.84, *P* <0.001), is because these two measurements have a direct influence on calculating pelvic area. It seems that in Dorper ewes, PW has a greater influence than PH on PA, judged by the correlation coefficients (0.94, vs. 0.84, respectively). This is contrary to what was reported for beef heifers, in which differences in pelvic areas are usually attributed to differences in pelvic height (Anderson & Bullock, 1994 and Patterson & Herring, 1997). Heritability of 50-60 % was found in sheep (Kinne, 2002) and 36-92 % in beef bulls (Deutscher, 1991), with pelvic height estimates more heritable than width estimates, and area is more heritable than height or width (Anderson & Bullock, 1994; Patterson & Herring, 1997). According to Briedenhann (2010), pelvic width is more important in *Bos taurus* cattle, while pelvic height is more important for ease of calving in *Bos indicus* cattle.

The correlation between the inside thigh and outside thigh (0.67, *P* <0.001), seems to have a significant influence on the assessment of conformation, as there is a 0.64 (*P* <0.001) correlation between conformation and the outside thigh and a 0.61 (*P* <0.001) correlation between conformation and the inside thigh. There is also a very high correlation (0.93, *P* <0.001) between conformation and selection where selection and outside thigh have a correlation of 0.68 (*P* <0.001) and selection and inside thigh have a correlation of 0.63 (P <0.001). A low correlation between body weight and pelvic area was recorded (0.241, P <0.001). The correlation (0.26, P <0.001) between rump slope and pelvic area is low. No comparable results in sheep literature could be found, but Philipson (1976) and Dadati,*et al.,* (1985) reported that a sloping rump was associated with calving ease. Van Zyl (2008) & Johnson *et al*, (1988) reported that rump slope has no influence on internal pelvic measurements and calving ease. The breed standards of the Dorper prescribe a flatter rump as opposed to most other sheep, goat and cattle breeds. In this study pelvic area and hindquarter width have shown a low correlation (0.25, P <0.001). It remains to be proven if phenotypic selection for conformation and type (i.e. flat rump, hindquarter width, muscling, etc) has indirectly affected pelvic measurements and ease of lambing in Dorper ewes.

Table 4: The effect of type on the pelvic area, pelvic width, pelvic height, body weight and hindquarter width of young Dorper ewes.

Parameter	Type 2	Type 3	Type 4	Type 5
Pelvic area $cm^2(\pi)$	33.51 ± 3.77^{a}	33.99 ± 5.30^{a}	36.72 ± 4.30^{b}	39.97 ± 4.30^{b}
Pelvic width (cm)	6.44 ± 0.39^{a}	6.39 ± 0.71^{a}	6.70 ± 0.43^{b}	6.73 ± 0.39^{b}
Pelvic height (cm)	6.60 ± 0.41^{a}	$6.74 \pm 0.45^{a, b}$	$6.96 \pm 0.44^{b, c}$	6.97 ± 0.44^{c}
Body weight (kg)	44.05 ± 6.23^{a}	$46.58 \pm 5.68^{a, b}$	48.93 ± 5.13^{b}	52.28 ± 4.76^{c}
Hindquarter width (cm)	17.86 ± 1.08^{a}	18.17 ± 1.02^{a}	18.38 ± 0.99^{a}	18.78 ± 0.96^{b}
	n = 22	n = 133	n = 141	n = 36

Means with different letters within the same row differ significantly: P < 0.05

In Table 4 it can be seen that there is no significant difference (P >0.05) between Type 2 and Type 3 ewes' pelvic areas, but there is a significant difference (P <0.05) in pelvic area of Type 3 and Type 4 ewes. Furthermore there is no significant difference (P >0.05) in pelvic areas of Type 4 and 5 ewes. The same tendency is applicable on pelvic width. From Table 3 it is also evident that stud ewes (Types 4 and 5) have wider pelvises than commercial ewes (Type 2 and Type 3). As in the case of pelvic height, there is no significant difference (P >0.05) between Type 2 and Type 3 ewes and between Types 3 and 4 ewes, but there is a significant difference (P <0.05) between Type 2 and Type 4 ewes' pelvic height. There is no significant (P >0.05) difference between Type 4 and Type 5 ewes' pelvic height, but there is a significant difference (P <0.05) between Type 3 and Type 5 ewes' pelvic height. In terms of body weight, there is no significant difference (P >0.05) between Type 3 and Type 4 ewes, but there is a significant difference (P <0.05) between Type four and Type five ewes.

It is clear that there is a difference of 6.46 cm^2 in pelvic area of Type 2 and Type 5 ewes (P <0.05), although a non- significant difference (P >0.05) between Type 2 and Type 3 ewes was recorded. It remains to be seen if such a small difference can significantly affect ease of lambing in young Dorper ewes. From Table 4 it can also be seen that selection Type 5 ewes are significantly (P <0.05) larger (heavier and with wider hindquarters) than all other selection Types (2, 3 and 4) that have similar body dimensions. Furthermore, no significant correlations could be established between linear body measurements and pelvic dimensions in ewes, indicating the need to directly measure the pelvic width and- height and to calculate its area if selection for larger pelvic areas (or culling of ewes with smaller PA) is intended

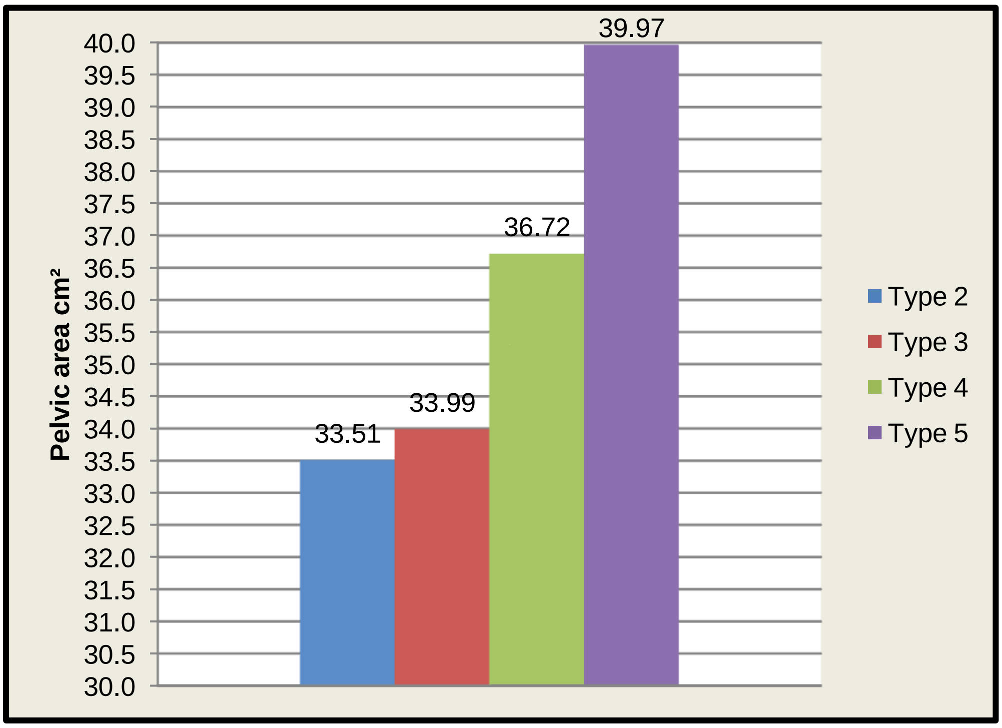

Figure 11: Differences in pelvic area between Type 2, Type 3, Type 4 and Type 5 ewes.

In Figure 11 it is clear that there is a difference of 6.46 cm² in pelvic area of Type 2 and Type 5 ewes (*P* <0.05), although a nonsignificant difference (*P* >0.05) between Type 2 and Type 3 ewes was recorded.

Table 5: Partial contribution of body measurements to pelvic area of Dorper ewes (n=332) with dependent variables in the top row and independent variables on the left-hand.

Parameter	**Pelvic area π**
Hindquarter width	0.0826
Conformation	0.0544
Rump slope (visually)	0.0187
Rump length	0.0156
Chest depth	0.0152
Chest projection	0.0081
Forequarter width	0.0069
Body weight	0.0066
Shoulder height	NS
Outside thigh	NS
Inside thigh	NS
Selection	NS
Model R^2	0.2081

All the variables in the model are significant at the 0.1500 level. No other variable met the 0.1500 significance level for entry into the model.

From Table 5 it is evident that body dimensions cannot be associated with pelvic dimensions. Hindquarter width, conformation, rump slope, rump length and chest depth were the most important factors influencing the pelvic area of ewes. If the low R^2 of 0.2081 is considered, it is evident that there are other factors that also have a significant influence on pelvic area.

4.6. Conclusions

Results of the present study indicated that the instrument and techniques developed in this study to obtain pelvic measurements in sheep were relatively easy and accurate. Overall it can be concluded that there is no significant relationship between pelvic dimensions and linear body measurements in Dorper ewes. This means that the pelvis must be measured directly and the areas calculated in order to eliminate ewes with smaller pelvic areas to reduce dystocia, as this parameter seems to be the most important factor influencing dystocia in females. Deutscher (1991) stated that pelvic area influences dystocia most of all the cow measurements. It is also clear that the pelvic areas of stud (Type 4 and Type 5) ewes are significantly bigger than those of commercial (Type 2 and Type 3) ewes. Measuring of pelvic areas must not be seen as the selection of the animals with the biggest pelvises, but elimination of animals with small pelvises (Van Zyl, 2008). Johnson *et al*. (1988) found that pre- breeding pelvic area could be used as an indicator of pre-calving pelvic area in cattle.

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CHAPTER 5

The relationship between pelvic dimensions and linear body measurements in Dorper rams

Abstract

Ewes with small pelvic areas are more prone to experience dystocia during parturition and high perinatal mortality. Selection for larger pelvic area should therefore be advantageous to producers. As the heritability for pelvic area ranges between 50-60%, it makes sense to include pelvic area as part of the selection criteria for rams in an attempt to ensure bigger pelvic areas in their female progeny. The main aims of this study were to develop two instruments to accurately measure the pelvic area (a pelvic meter) and the rump slope in small stock and to quantify the relationship between a number of easy to measure external linear body measurements and pelvic dimensions of young Dorper rams. The pelvic meter developed was pre-tested on 90 sheep prior to slaughtering at an abattoir and shortly after post mortem. The correlation between the pre- and post- slaughter measurements was highly significant ($P < 0.05$; r=0.85).

A study was carried out using 272 young Dorper rams participating in the Northern Cape (NC) veld-ram project. These animals were managed and performance tested under the same extensive conditions on veld, receiving only a phosphate lick (±30 gram/animal/day) as supplement. The rams' pelvic areas were measured trans-rectally five times, at 40 days intervals between the ages of 223 ± 41 and 385 ± 41 days. The height of the pelvis was obtained by measuring the distance between the dorsal *pubic tubercle* on the floor of the pelvis and the *sacrum* (spinal column) on the top. The width of the pelvis was measured as the widest distance between the right and the left shafts of the *ilium* bones. The pelvic area was calculated using the π (PH/2)*(PW/2) formula.

Other body measurements such as body weight and length, heart girth, chest depth, forequarter width, hindquarter width, rump length, rump slope and the distance between the pin bones were measured on the last day of the trial and correlated with the pelvic area of the ram. The slope of the rump was measured in degrees with an instrument that was developed for this purpose. Results indicate

that there are no significant correlations between the pelvic dimensions and any other body measurements considered in this study. Selection for larger pelvic areas in rams therefore requires direct pelvis measuring. Both the pelvic meter and the rump slope meter specially developed for this study proved to be accurate and relatively practical to use in Dorper rams.

Keywords: Pelvic meter, pelvic dimensions, linear body measurements, Dorper rams

5.1. Introduction

In sheep, a small pelvic area is associated with dystocia, which is a major cause of perinatal mortality and is associated with poor lifetime rearing performance of ewes (Haughey & Gray, 1982; Kilgour & Haughey, 1993; Hartwig, 2002). It would thus make sense to include pelvic area as a criterion to select breeding ewes; however its measuring *in vivo* poses some practical challenges due to the reduced size of sheep, when compared to cattle. According to Kilgour & Haughey (1993), indirect criteria for selection for improved lamb survival can be made on rams, with the measuring of pelvic size. As rams contribute 50% of the genetic make-up of their progeny and the heritability of pelvic area is medium to high (around 50-60%) in sheep (Kinne, 2002), indirect selection for improved perinatal lamb survival can be made by selecting rams with larger pelvic areas (Kilgour & Haughey, 1993). Laster (1974) stated that no external measurements could be actually correlated to predict pelvic area or to identify pelvic abnormalities. He also stated that pelvic area should be measured directly. Besides being difficult to measure, there are no pelvic meters and well established techniques for sheep available in the market. It would be of great practical value to find traits (i.e. external body measurement) highly correlated with pelvic measurements (height, width and area) or when these are absent, to develop a pelvic meter and measuring technique which are reasonably easy and accurate to be used in sheep.

The aims of this study were thus to develop an instrument and a technique to measure the pelvises (height and width) of small stock and to investigate and quantify the correlations between pelvic measurements (height, width and area) and some external linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length, etc) in Dorper rams.

5.2. Material and Methods

5.2.1. Animals

All 272 Dorper rams participating in the 2009/10 Northern Cape veld-ram project (Niekerkshoop area) were used in this study. All the animals were managed extensively and performance tested under the same conditions on the veld between 6 and 13±1 months of age, receiving only a maintenance phosphate lick. The rams were measured five times during the project from the age of seven to thirteen months with 40-day intervals.

5.2.2. Environment

Central Northern Cape (Niekerkshoop area)

The veld type covers most of the Griqualand West region of sweet-mixed bushveld on rocky soil. The rainfall, occurring in summer, ranges from 250 mm to 350 mm and is very erratic. The summers are hot, while the winters are frosty. The underlying rock is dolomite. The grass is by nature tall, and is dominated by *Themeda triandra* and *Cymbopogon plurinodis,* with much *Aristida diffusa, Stipagrostis uniplumis, Eragrostis lehmanniana, Heteropogon contortus, Digitaria eriantha, Chrysopogon serrulatis* and *Eustachys* spp (Acocks, 1988). Both grazers and browsers are adaptable to this veld type. However, the forage supply from season to season is extremely variable.

5.2.3. Instruments

5.2.3.1. Pelvic meter

A pelvic meter for sheep was developed in collaboration with the Science Park of the CUT (Central University of Technology, Free State). The pelvic meter developed was pre-tested at the Bloemfontein abattoir on 90 randomly selected sheep prior to slaughtering and shortly after slaughtering. The correlation between the pre- and post- slaughter measurements was highly significant (height 0.80 P <0.05: width 0.87 P <0.05; area 0.85; P <0.05). A pelvic meter is presented in Figure 12.

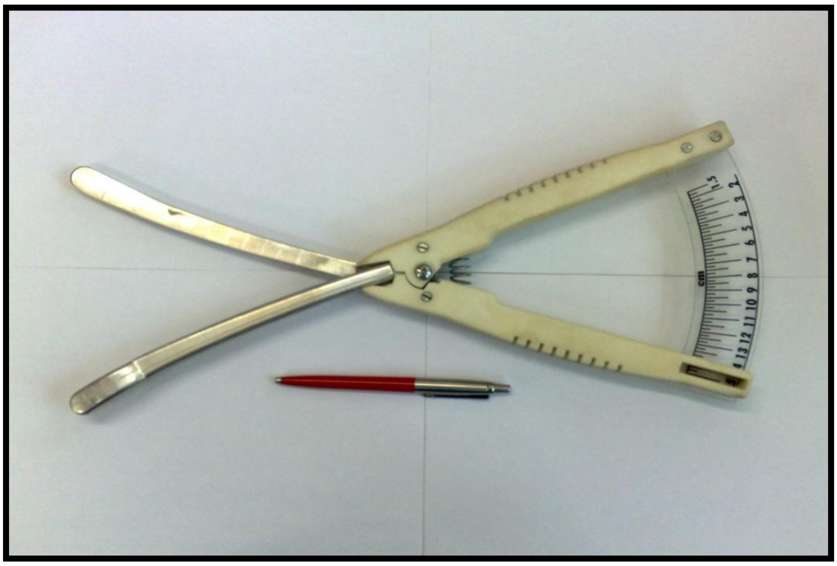

Figure 12: Pelvic meter that was used to measure pelvic dimensions in rams.

5.2.3.2. Rump slope meter

The slope of the rump was measured in degrees with an instrument that was developed. In Figures 13 and 14 the rump slope meter can be seen.

Figure 13: Side view of the rump slope meter

Figure 14: Hind view of the rump slope meter

5.3. Measurements

5.3.1. Pelvic measurements

Figure 15 demonstrates the pelvic measurements. Pelvic height (PH) was taken between the *sacrum* (spinal column) and the *dorsal pubic tubercle* floor on the pelvis. Pelvic width (PW) 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; Van Zyl, 2008)

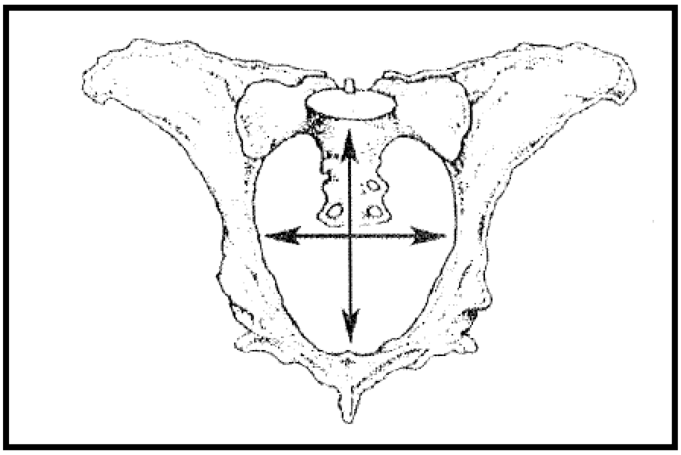

Figure 15: Measurement areas for the pelvis (Anderson & Bullock, 1994).

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 were then removed from the rectum if necessary and the instrument was carefully placed into the rectum (Deutscher, 1975, Van Zyl, 2008). 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 15). 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 15). 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; Van Zyl, 2008). 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 Zyl, 2008). All measurements were taken in centimetres.

The measurements were calculated as follows: Pelvic area = π (PH/2)*(PW/2) (Morrison *et al*., 1986). Pelvic area is a criterion which can be used to cull or keep ewes or rams (Van Zyl, 2008).

5.3.2. Rump slope measurements

The slope of the rump was measured from the *tuber ischii* (Pin bone) to the *tuber coxae* (hip bone) on the left side of the animal (Figure 16).

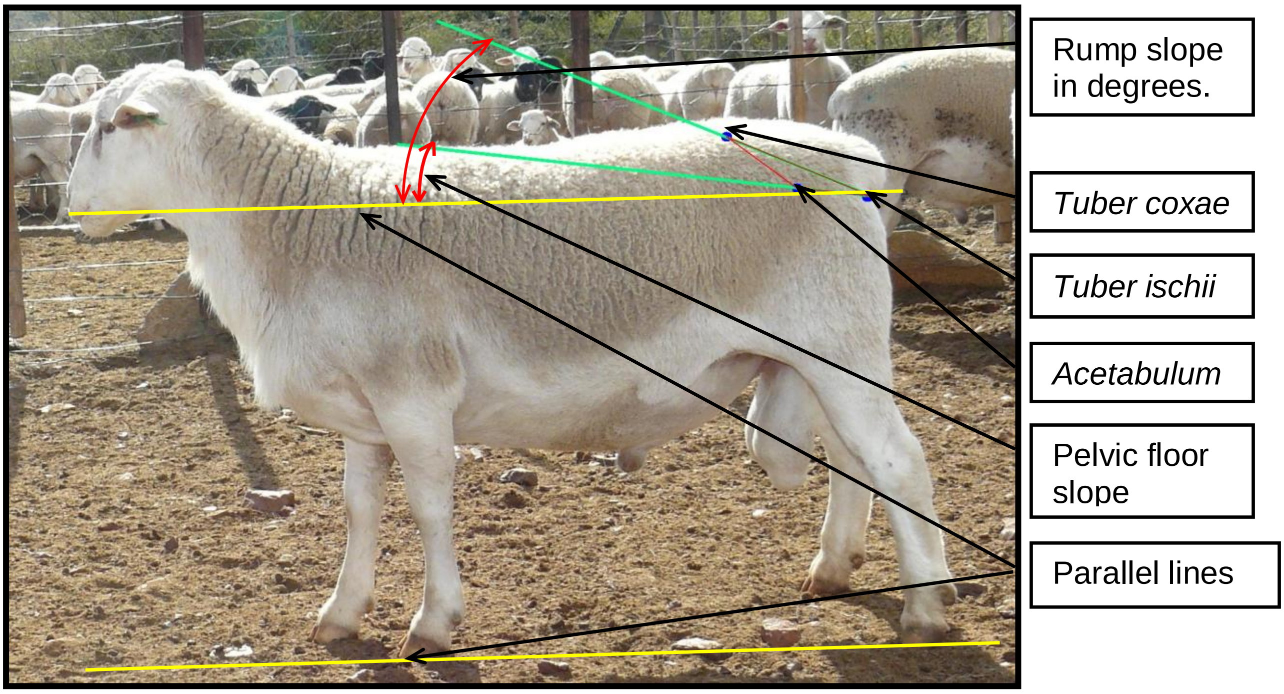

Figure 16: Illustration of how rump slope was measured with the rump slope measuring instrument

5.3.3. Body measurements:

The following data / measurements were recorded during and at the end of the trial:

- Age in days
- Body weight (kg) following a 12-hour fasting period.
- Shoulder height (cm), measured vertically from the *thoracic* vertebrae to the ground (Fourie *et al*., 2002).
- Body length (cm) as measured from the sternum (*manubrium*) to the aitchbone (*tuber ischiadicum*) (Fourie *et al*., 2002).
- Heart girth was measured with a measuring tape around the chest just behind the front legs (Fourie *et al*., 2002).
- Chest depth was measured from the *spianus* to the *xyfoid* process of the sternum (Fourie *et al*., 2002).
- Forequarter width was measured from the left *scapula* to the right *scapula*.
- The hindquarter width was measured between the left thurl to the right thurl.
- Distance from the *tuber coxae* to the pin bone.
- Distance from the pin bone to the *acetabulum*.
- Distance from the *acetabulum* to the *tuber coxae*.

- Inside width between the pin bones.
- Slope of the rump in degrees.
- Scrotal circumference (cm).
- Height from the ground to the *carpus* (cm).
- Height from the ground to the *olecranon* (cm).
- Body condition score (on a 5 point scale with 1 being very lean and 5 very fat).

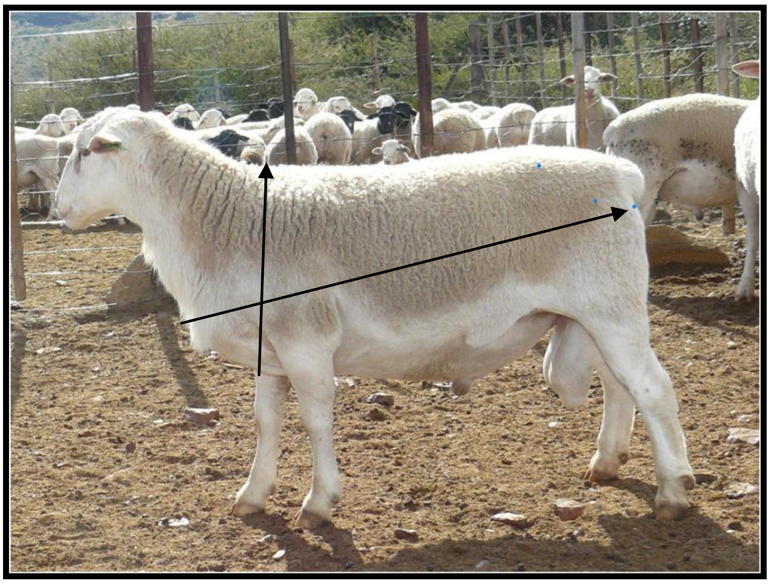

Figure 17: An illustration of where to measure some of the measurements.

5.4. Data analysis

Analysis of variance was conducted to determine the relationship between parameters. Data were analysed using the General Linear Model procedures of SAS (SAS, 1989). Product moment correlations between variables were calculated. A stepwise regression was carried out to determine the individual influence of body measurements on pelvic area. An F to enter the level of 0.10 was used to determine the significance of the partial contribution of each effect. Pelvic area was included as covariate.

5.5. Results and Discussion

As can be seen in Table 6, the mean difference between pelvic height and pelvic width is very slight. The difference in pelvic size is usually attributed to the difference in the pelvic height (Anderson & Bullock, 1994 and Patterson & Herring, 1997). Heritability of pelvic height is greater than that of pelvic width. Pelvic area is more heritable than pelvic width or pelvic height (Boyles, 2000).

Table 6: Mean ± standard deviation (s.d.) of parameters measured during the trial of the Dorper rams.

Parameter	Rams Mean ± s.d.
Body length (cm)	71.2 ± 2.57
Shoulder width (cm)	22.9 ± 1.36
Chest depth (cm)	28.7 ± 2.49
Hindquarter width (cm)	24.1 ± 1.53
Shoulder height (cm)	64.1 ± 2.63
Rump slope (°)	34.2 ± 5.22
Coxae to pin bone (cm)	23.4 ± 1.79
Pin bone to *acetabulum* (cm)	12.4 ± 1.49
Acetabulum to *tuber coxae* (cm)	14.1 ± 1.74
Heart girth (cm)	86.8 ± 3.70
Pelvic height (cm)	6.44 ± 0.42
Pelvic width (cm)	5.56 ± 0.37
Width between pin bones (cm)	5.14 ± 0.33
Body condition score	3 ± 0.67
Pelvic area (cm^2)	28.22 ± 3.21
Body weight (beginning; kg)	41.49 ± 5.35
Body weight (end; kg)	54.11 ± 5.41
Scrotal circumference (beginning; cm)	30 ± 2.43
Scrotal circumference (end; cm)	36 ± 2.32
Selection index	102 ± 9.37
Ground to *carpus* (cm)	21 ± 0.93
Ground to *olecranon* (cm)	39 ± 1.62
Age in days	385 ± 40.65

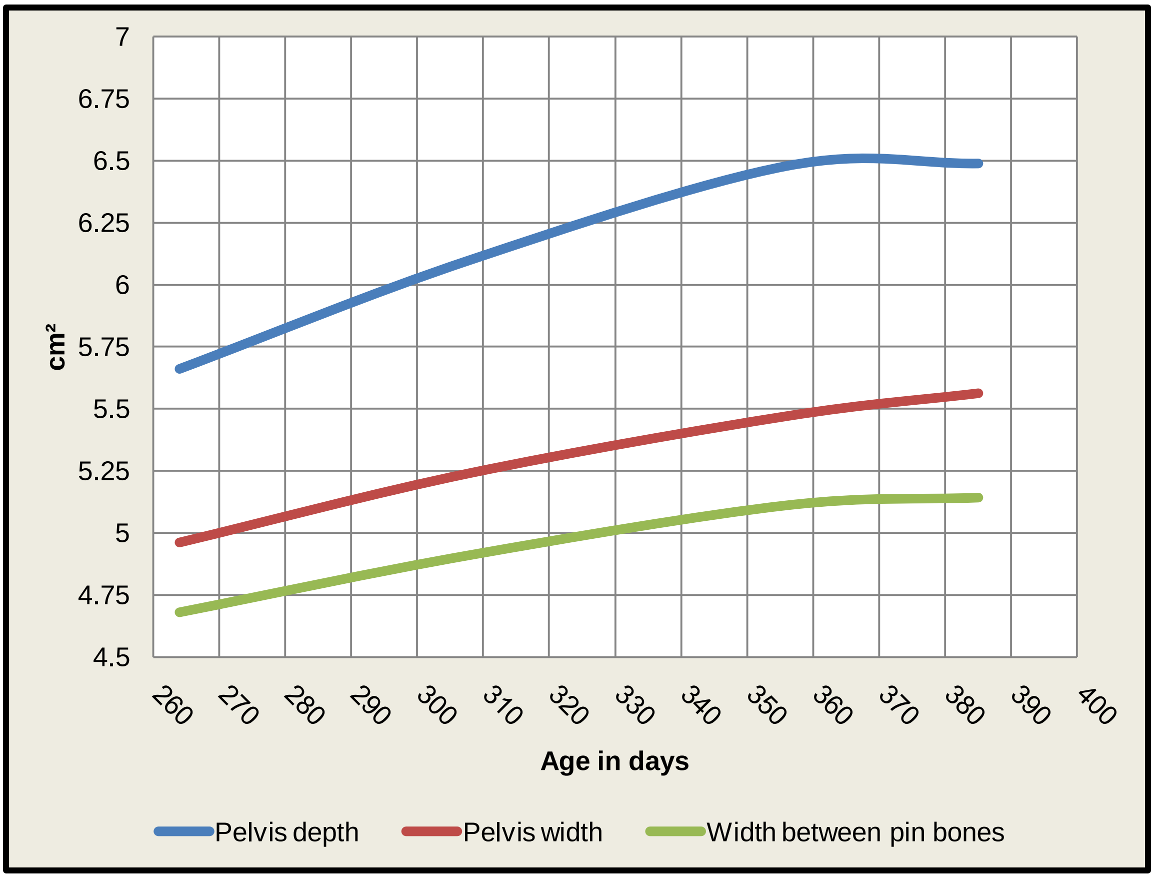

Figure 18: The growth of pelvic height, pelvic width and pin bones over a period of 121 days (measured 4 times).

Figure 18 clearly depicts that the growth tendency of the three measurements is almost linear, although pelvic height has a slightly different growth pattern when reaching maturity at approximately 370 days. Width between the pin bones grows linear with the width of the pelvic itself and has a correlation of 0.855 (Table 8).

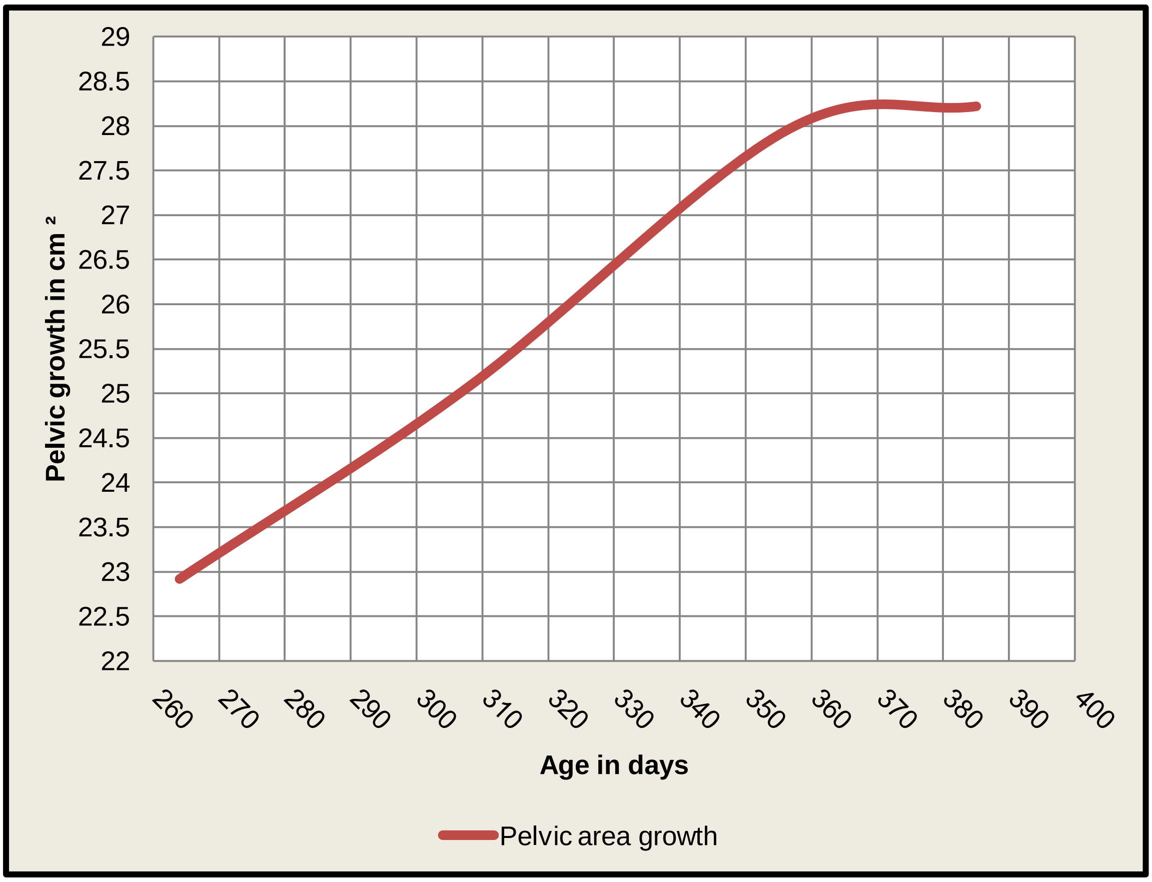

Figure 19: The growth of the pelvic area of Dorper rams over a period of 121 days.

In Figure 19 it can clearly be seen that the pelvic area of Dorper rams increases until reaching maturity (± 370 days). After that, the growth of the pelvis tends to move sideways.

Table 7: Partial contribution of body measurements of Dorper rams (n=270) with dependent variables in the top row and independent variables on the left-hand.

Parameter	Pelvic area π
Age	0.1656
Shoulder height	0.0404
Scrotal circumference	0.0105
Body weight	NS
Body length	NS
Heart girth	NS
Chest depth	NS
Forequarter width	NS
Hindquarter width	NS
TC-PB	NS
PB-AC	NS
AC-TC	NS
Rump slope (°)	NS
Ground to *carpus*	NS
Ground to *olecranon*	NS
Body condition score	NS
Breeder	NS
Model R^2	0.2341

TC-PB = From *tuber coxae* to the pin bone; PB-AC = From pin bone to *acetabulum*; AC-TC = From *acetabulum* to *tuber coxae*. All the variables in the model are significant at the 0.1500 level. No other variable met the 0.1500 significance level for entry into the model.

The stepwise regression analysis demonstrated that the combined contribution of all linear body measurements considered in this model on pelvic area in Dorper rams was only 0.23, indicating that there are other more important factors influencing pelvic area. The most important being pelvic related measurements (pelvic height and width as well as distance between the pin bones).

Table 8: Phenotypic correlations between parameters of Dorper rams**.**

Parameter	BL	SW	CD	HW	SH	RS	TC-PB	PB-AB	AB-TC	HG	PH	PW	WBP	BCS	PA	BW	SC	SI	GC	GO
BL																				
SW	0.371																			
CD	0.347	0.327																		
HW	0.278	0.451	0.273																	
SH	0.463	0.276	0.281	0.220																
RS	-0.147	-0.025	-0.087	0.055	0.077															
TC-PB	0.232	0.086	0.133	0.140	0.163	-0.195														
PB-AB	0.215	-0.016	0.030	0.023	0.075	-0.209	0.465													
AB-TC	0.100	0.110	0.008	0.172	0.144	-0.032	0.543	-0.067												
HG	0.491	0.624	0.427	0.437	0.374	0.019	0.273	0.095	0.163											
PH	0.226	0.089	0.101	0.085	0.252	0.038	0.154	0.053	0.065	0.221										
PW	0.252	0.205	0.138	0.157	0.143	-0.002	-0.023	0.012	0.016	0.220	0.481									
WBP	0.252	0.252	0.167	0.147	0.143	0.027	-0.005	0.053	-0.011	0.256	0.424	0.855								
BCS	0.286	0.411	0.214	0.397	0.157	-0.049	0.097	-0.018	0.103	0.453	0.046	0.135	0.104							
PA	0.276	0.173	0.135	0.141	0.228	0.019	0.073	0.035	0.045	0.253	0.855	0.865	0.747	0.103						
BW	0.659	0.664	0.453	0.483	0.489	-0.042	0.235	0.099	0.141	0.824	0.253	0.313	0.331	0.459	0.327					
SC	0.180	0.110	0.176	0.135	0.206	-0.017	0.106	-0.028	0.168	0.153	-0.033	0.091	0.115	0.235	0.031	0.282				
SI	0.349	0.383	0.216	0.239	0.340	-0.015	0.131	-0.030	0.191	0.500	0.130	0.184	0.172	0.251	0.182	0.623	0.301			
GC	0.366	0.159	0.188	0.119	0.504	0.080	0.126	0.112	0.079	0.197	0.065	0.000	0.032	0.049	0.039	0.333	0.222	0.238		
GO	0.385	0.160	0.262	0.096	0.604	0.084	0.263	0.109	0.175	0.308	0.211	0.077	0.71	0.109	0.167	0.400	0.178	0.203	0.627	

Body length (BL), Shoulder width (SW), Chest depth (CD), Hindquarter width (HW), Shoulder height (SH), Rump slope in degrees (RS), *Tuber coxae* to the pin bone (TC-PB), Pinbone to the *acetabulum* (PB-AB), *Acetabulum* to the *tuber coxae* (AB-TC), Heart girth (HG), Pelvic height (PH), Pelvic width (PW), Width between pin bones (WBP), Body condition score (BCS), Pelvic area (PA), Body weight (BW), Scrotal circumference (SC), Selection index (SI), Ground to *carpus* (GC), Ground to *olecranon* (GO).

It can be seen in Table 8 that there is a medium correlation (0.62, *P* <0.001) between shoulder width and heart girth. There is also a medium correlation (0.66, *P* <0.001) between body weight and body length as well as between shoulder width and body weight (0.66, *P* <0.001). A high correlation (0.82, *P* <0.001) between heart girth and body weight is recorded. Similarly there is a high correlation (0.86, *P* <0.001) between pelvic area and pelvic height as well as between pelvic area and pelvic width (0.87, *P* <0.001). This correlation is understandably high as pelvic height and pelvic width directly influence pelvic area. A high correlation is evident between pelvic width and width between the pin bones (0.86, *P* <0.001). Therefore, it seems that the distance between the pin bones, a measurement that can also be taken externally, is a relatively good estimator for pelvic area in rams. The selection of rams with wider distances between pin bones should therefore result in the selection of rams with larger pelvic areas.
There is also a medium to high correlation of 0.75 (*P* <0.001) between pelvic area and width between the pin bones. There is a very low correlation (0.14, *P* <0.001) between hindquarter width and pelvic area as well as between hindquarter width and pelvic width (0.16, P <0.001). Despite the fact that the Dorper breed standards emphasise wide hindquarters (for meat), very low correlations were recorded between hindquarter width and pelvic measurements (height, width and area). Similar results were found for all other rump measurements considered (Table 8). Heritability of pelvic area of 50-60 % was found in sheep (Kinne, 2002) and 36-92 % in beef bulls (Deutscher, 1991), with pelvic height estimates more heritable than width estimates, while area is more heritable than height or width (Anderson & Bullock, 1994 and Patterson & Herring, 1997).

The slope of the rump in Dorper rams have a very low correlation of 0.02 (*P* <0.001) with pelvic area. No comparable results were found in sheep literature, but Philipson (1976) and Dadati *et al.,* (1985) reported that a sloping rump was associated with calving ease. In contrast, Van Zyl (2011) reported that rump slope does not influence pelvic area or calving ease. Cloete *et al.,* (1998) mentioned that a sloping rump was associated with shorter parturition periods in Mutton Merino ewes. There is also a 0.46 (*P* <0.001) correlation between body condition score and body weight. The low correlation (0.10 *P* <0.001) between body condition score and pelvic area is an indication that the pelvic measurements were not affected by the condition of the animals.

5.6. Conclusions

Results of the present study indicated that the instrument and techniques developed in this study to obtain pelvic measurements in sheep are relatively easy to use and accurate. The correlations between pelvic measurements (internal measurements) and external body measurements are generally low. These results further indicate the need to directly measure the pelvises of rams in order to calculate the pelvic area. However, the width between pin bones was highly correlated with pelvic area. This measurement can also be taken externally more easily than internally and therefore this parameter may seemly be used as an indirect estimator of pelvic area. As the heritability of pelvic area is relatively high and small pelvic area is a major contributor to dystocia, it follows to include pelvic area as a selection criterion for rams in an attempt to reduce dystocia in their female offspring. Pelvic measurements should be included in the performance figures of rams in Veld-ram projects

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CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusion

- **Farmer's opinion of the Dorper breed with regard to certain productive and functional traits.**

  An alarming response is that 36% of the respondents reported an increase in dystocia among Dorper ewes. As a result of this, 10.6% of the farmers use other rams, like the Damara, Meatmaster, Persian and Van Rooy breeds, to mate their young ewes with. From the survey study it is also evident that farmers (36%) are of the opinion that the hardiness of the breed had declined.

- **The pelvic meter**
- The pelvic meter, specially developed for this study, proved to be a useful tool and relatively practical to use in Dorper sheep.

- **Body and pelvic measurement relationships in ewes**

  The high mortality rate that has been associated with dystocia raised a need to investigate some possible solutions in minimizing dystocia in sheep. In this study it was found that measuring the pelvis is not the cure-all solution for dystocia, but one criterion which the farmer can use to select breeding ewes.

  It can be concluded that there is no significant relationship between pelvic dimensions and linear body measurements in Dorper ewes. It is also clear that the pelvic areas of stud (Type 4 and Type 5) ewes are significant bigger than those of commercial (Type 2 and Type 3) ewes.

- **Body and pelvic measurement relationships in rams**

  The ram has a significant influence on a herd, especially when it is considered that his pelvic area is between 50-60% heritable in his female progeny. This emphasises the importance of selecting breeding rams with adequate pelvic areas.

  It is evident that there is no significant relationship between pelvic dimensions and linear body measurements in Dorper rams. Therefore, the pelvis must be measured in order to make a conclusion. The width between pin bones recorded high correlations with pelvic area and can be measured externally, easier than internally. Therefore this parameter may seemingly be used as an indirect estimator of pelvic area. Pelvic measurements as a selection criterion can be conducted when a ram reaches the age of ±365 days. Due to the high heritability of pelvic area, the selection for larger pelvic area in rams should result in increased pelvic size of female offspring.

6.2. Recommendations

- As the pelvic meter was proven to be reliable and practical, it is recommended that the pelvic area of young ewes be measured prior to mating in order to reduce dystocia.
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- Measuring of pelvic areas must not be seen as the selection of the animals with the biggest pelvises, but rather a method of elimination of animals with small pelvises.
-
- Farmers and breeders must not rely on visual appraisal to select against difficult lambing, but rather on the reproductive performance and pelvic measurements of animals.

- It is also recommended that pelvic measurements be included in the performance figures of rams at Veld Ram projects.

- In view of the seeming deterioration in hardiness, the Dorper breeders' society will have to implement measures to restore the breed to levels of 30 years ago, in terms of this important trait.

Addendum A

Scientific articles submitted to the South African Journal of Animal Science

Relationship between pelvic and linear body measurements in Dorper ewes

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Abstract

High perinatal mortality (ewe and lambs) and low lifetime rearing success have been associated with small pelvic areas of ewes. It would thus make sense to include pelvic area as a criterion to select breeding ewes; however measuring it *in vivo* poses some challenges. The aim of this study was to investigate and quantify the correlations between pelvic measurements (height, width and area) and a number of easy to measure external linear body parameters (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length, etc) in Dorper ewes, as well as to investigate whether the selection according to breed standards resulted in indirect selection for ewes with different pelvic areas. In this study, the pelvises, body weight and certain linear body measurements of 332 young Dorper ewes (± 12 months old; 48.0 ± 5.9 kg) were taken. The overall mean pelvic area of yearling Dorper ewes was 35.44 ± 4.9 cm^2. Stud ewes recorded significantly higher pelvic areas (37.38 ± 4.3 cm^2) than commercial ewes (33.92 ± 3.8 cm^2). Results also indicated no significant correlations between pelvic measurements and all other body measurements considered in this study, indicating the need to directly measure the pelvic area of ewes. The pelvic meter and techniques specially developed for this study proved to be very useful to measure the pelvises of sheep, being very accurate and relatively easy to use in ewes.

Keywords: Pelvic meter, pelvic dimensions, linear body measurements, pelvis, dystocia, Dorper ewes

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Introduction

Small pelvises in ewes are associated with a high incidence of dystocia, high perinatal mortality rates (ewe and lamb) and poor lifetime rearing performance of ewes (Haughey & Gray, 1982; Kilgour & Haughey, 1993; Hartwig, 2002). In addition, dystocia is associated with prolonged postpartum periods, uterine infections and increased non-reproductive days, as well as reductions in overall conception rate and milk production (Sieber *et al.*, 1989; Walker *et al.*, 1992). It would thus make sense to include pelvic area as a criterion in selecting breeding ewes (or rather to eliminate ewes with small pelvic areas); however it's *in vivo* measuring poses some practical challenges (internal measurement) due to the reduced size of sheep when compared to cattle.

Body size (length, height, etc) and conformation can be easily measured or described by visual assessment. How these measurements relate to the functional efficiency of the animal is of paramount importance to livestock production. Therefore, constant checks on the relationships between body measurements and productive and reproductive performances are vital in selection programs (Maiwashe, 2000). The aim of this study was to investigate and quantify the correlations between pelvic measurements (height, width and area) and other easier to measure external linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length, etc) in Dorper ewes, as well as to investigate if the selection according to breed standards resulted in indirect selection for different pelvic areas in ewes.

Materials and methods

A total of 332 Dorper ewes (± 12 months old; 48.0 ± 5.75 kg) from three different breeders were managed extensively on veld and received only salt lick supplementation in the Central Northern Cape region. A pelvic meter was specially developed for sheep and goats, in collaboration with the Science Park of the CUT (Central University of Technology, Free State) and pre-tested at the Bloemfontein abattoir on 90 randomly selected sheep just prior to and after slaughtering. The correlation between the pre- and post-slaughter pelvic measurements (height 0.80 $P < 0.05$: width 0.87 $P < 0.05$; area 0.85; $P < 0.05$) was very high.

The pelvises of all the ewes were measured once, using a method adapted from Haughey & Gray, (1982); Walker *et al.*(1992), Kilgour & Haughey, (1993); and Patterson & Herring, (1997). The ewe was restrained by standing in a chute with light squeeze, faeces were removed from the rectum by gentle digital manipulation and the lubricated forceps of the instrument was carefully placed into the rectum (Deutscher, 1975). After inserting the pelvic meter into the animal's rectum, the forceps were opened while applying light pressure on its handle. The instrument was then slightly twisted from left to right while being inserted, so that the operator could feel the ossified joint on the *symphysis pubica*, to find the point to measure the pelvic height (PH, longest distance between the *pubic tubercle* on the floor of the pelvis and the sacrum on the pelvic roof). The instrument was then turned about 90° sideways at the same point (pelvic inlet at its widest point), to measure the pelvic width (PW, longest distance between the right and left *corpura ilii*). The instrument was thoroughly cleaned with a mild disinfectant solution after each animal was measured. The pelvic area of each animal was calculated as π (PH/2)*(PW/2) (Morrison *et al.*, 1986).

The following linear body measurements were also taken as described by Fourie *et al*. (2002) and correlated with the pelvic height (PH), width (PW) and area (PA): body weight (BW); shoulder height (SH); chest depth (CD); shoulder width (SW); hindquarter width (HW) and rump length (RL). In addition, the ewes were assessed visually for conformation (CM) and, selection Type (S); as described by the Dorper breed standards of excellence, on a scale of 1-5 (Fourie *et al*., 2002). Conformation 1= very poor and 5= very good; selection Type 1= cull, 2= 2nd selection, 3= commercial, 4= Type 4 stud and 5= Type 5 stud, as well as rump slope (RS), from 1= very flat to 5= very droopy).

Analyses of variance were conducted to compare means of different parameters using GLM (General Linear Model) procedures of SAS (SAS, 1989). Product moment correlations between the variables were also calculated.

Results and Discussions

The means and standard deviations (s.d.) for the different body parameters considered in this study are presented in Table 1.

Table 1 Mean and standard deviation (s.d.) for body measurements in yearling Dorper ewes.

Parameter	Mean ± s.d.
Body weight (kg)	48.0 ± 5.75
Shoulder height (cm)	60.9 ± 2.43
Chest depth (cm)	29.1 ± 1.33
Shoulder width (cm)	21.5 ± 1.22
Hindquarter width (cm)	18.3 ± 1.02
Rump length (cm)	20.4 ± 1.22
Pelvic width (cm)	6.6 ± 0.45
Pelvic height (cm)	6.9 ± 0.46
Pelvic area (cm^2)	35.55 ± 4.89
Conformation	3.5 ± 0.64
Selection	3.6 ± 0.77
Chest projection	3.7 ± 0.47
Rump slope	3.6 ± 0.56

Table 1 gives an overview of the means of some of the body dimensions of Dorper ewes

The mean values for PH and PW in 12 months old Dorper ewes were very similar and PA recorded a small variance amongst yearling ewes. The same trend was observed for most other body measurements considered in this study (Table 1).

Table 2 depicts the correlation coefficients between pelvic measurements and most variables considered in this study. In general, all pelvic measurements recorded high correlations between each other and very low correlations with all other body measurements considered. The very high correlations recorded between PW and PA (0.94, $P < 0.001$), as well as between PH and PA (0.84, $P < 0.001$) can be explained by the fact that these two measurements (PH and PW) are factors on the formula to estimate PA. The correlation between PH and PW was also high (0.77, $P < 0.001$). Smith (2005) stated that the growth in pelvic height and pelvic width differs between different frame sizes of beef heifers. According to Briedenhann (2010), for ease of calving, pelvic width is more important in *Bos taurus* cattle, while pelvic height is more important in *Bos indicus* cattle. It seems that in Dorper ewes, PW has a greater influence than PH on PA, judging by the correlation coefficients (0.94 vs. 0.84 respectively). This is contrary to what was reported for beef heifers, where, differences in pelvic areas are usually attributed to differences in pelvic height (Anderson & Bullock, 1994; Patterson & Herring, 1997).

Table 2 Phenotypic correlations between pelvic measurements and certain linear body measurements parameter in Dorper ewes

Parameter	BW	SH	CD	SW	HW	RL	PW	PH	PA	S	RS
Pelvic width	0.26	0.12	0.24	0.11	0.30	0.04	-	0.77	0.94	0.26	0.20
Pelvic height	0.24	0.09	0.24	0.10	0.24	0.03	0.77	-	0.84	0.25	0.27
Pelvic area	0.24	0.10	0.26	0.12	0.25	0.05	0.94	0.84	-	0.27	0.26

Body weight (BW), Shoulder height (SH), Chest depth (CD), Shoulder width (SW), Hindquarter width (HW), Rump length (RL), Pelvic width (PW), Pelvic height (PH), Pelvic area (PA), Conformation (CM), Selection (S), Chest projection (CP), Rump slope (RS).

Low to very low correlations were found between BW, SH, CD, HW, RL, S and RS and PH, PW and pelvic measurements in sheep; however PA generally recorded the highest r^2 values (Table 2). In addition, the correlations between PA and all hindquarter measurements (RL, RS and even hindquarter width) were also low to very low (0.045-0.256, P <0.001). No similar studies to compare results could be found in the literature for sheep. Johnson *et al*. (1988) reported that rump slope has no influence on internal pelvic measurements or calving ease. However, Philipson (1976) and Dadati *et al.*, (1985) reported that in cattle, a sloping rump was associated with calving ease. The breed standards of the Dorper sheep prescribe a flatter rump as opposed to most other sheep, goat and cattle breeds. It remains to be proven if phenotypic selection pressures for conformation and Type (i.e. flat rump, hindquarter width, muscling, etc) have indirectly affected pelvic measurements and ease of lambing in Dorper ewes. Table 3 depicts the mean pelvic measurements, body weight and hindquarter width for different ewe types as classified according to breeding standards (from 2&3 = commercial to 4&5 = Stud).

Table 3 The relationship between body weight, hindquarter width and pelvic width, height and area and selection type of yearling Dorper ewes

Parameter	Type 2	Type 3	Type 4	Type 5
Number of observations	n = 22	n = 133	n = 141	n = 36
Pelvic width (cm)	6.44 ± 0.4^{a}	6.39 ± 0.7^{a}	6.70 ± 0.4^{b}	6.73 ± 0.4^{b}
Pelvic height (cm)	6.60 ± 0.4^{a}	$6.74 \pm 0.5^{a,b}$	$6.96 \pm 0.4^{b,c}$	6.97 ± 0.4^{c}
Pelvic area $cm^2(\pi)$	33.51 ± 3.8^{a}	33.99 ± 5.3^{a}	36.72 ± 4.3^{b}	39.97 ± 4.3^{b}
Body weight (kg)	44.05 ± 6.2^{a}	$46.58 \pm 5.78^{a,b}$	48.93 ± 5.1^{b}	52.28 ± 4.8^{c}
Hindquarter width (cm)	17.86 ± 1.1^{a}	18.17 ± 1.0^{a}	18.38 ± 1.0^{a}	18.78 ± 1.0^{b}

^{a,b,c} Means with different superscripts within the same row differ significantly at $P < 0.05$

In Table 3 it can be seen that there were generally no significant differences (P >0.05) in pelvic measurements between Types 2 and 3 (commercial) or Types 4 and 5 (stud) ewes' pelvic areas, however Types 4 and 5 ewes recorded significantly higher pelvic height, width and area than Types 2 and 3 ewes (P <0.05). The exception was the similar pelvic height of Types 3 and 4 ewes. Although relatively small, Type 5 ewes recorded a mean pelvic area 6.46 cm² larger than Type 2 ewes (P <0.05). It remains to be seen if such a small difference can significantly affect ease of lambing in young Dorper ewes.

Table 3 also shows be seen that selection Type 5 ewes are significantly (P <0.05) larger (heavier and with wider hindquarters) than all other selection Types (2, 3 and 4) with similar body dimensions. Furthermore, no significant correlations could be established between linear body measurements and pelvic dimensions in ewes, indicating the need to directly measure the pelvic width and -height and to calculate its area if selection for larger pelvic areas (or culling of ewes with smaller PA) is intended. In a stepwise regression analysis, hindquarter width, body conformation, rump slope, rump length and chest depth were the most important traits influencing the pelvic area of ewes. However, the combined contribution of all these variables to the model discussed above was only 0.208, indicating that there are other more important factors influencing pelvic area.

Conclusions

Results of the present study indicated that the instrument and techniques developed in this study to obtain pelvic measurements in sheep are relatively easy and accurate. It can also be concluded that there are generally no significant correlations between linear body measurements and pelvic dimensions in yearling Dorper ewes. This means that the pelvises must be measured directly and the areas calculated in order to eliminate ewes with smaller pelvic areas with the aim of reducing dystocia, as this parameter seems to be the most important factor influencing dystocia in females. Stud Dorper ewes (Types 4 and 5) recorded significantly higher pelvic dimensions than commercial Types (2 and 3). The pelvic meter specially developed for this study, proved to be a very useful tool to measure the pelvises of sheep, being very accurate and relatively easy to use in ewes.

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Relationship between pelvic dimensions and linear body measurements in Dorper rams

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Abstract

Dystocia is a major cause of perinatal mortality in sheep and it seems to be associated with small pelvic areas in ewes. As the heritability of pelvic area is relatively high, it makes sense to include pelvic areas as a selection criterion for rams in order to reduce dystocia in their female offspring. However measuring the pelvises of sheep poses some practical challenges.

A study aiming at developing an instrument and techniques to measure the pelvises of sheep trans-rectally was conducted on Dorper rams, using 272 yearlings. The correlations between pelvic measurements (height, width and area) and a number of easy to measure external linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length and body weight) in Dorper rams were investigated. The pelvic meter, specially developed for this study, proved to be a very useful tool to measure the pelvises of sheep, being very accurate and relatively easy to use in rams. The correlations between pelvic measurements (internal measurements) and linear body measurements (external) were generally very low (<0.2), indicating the need to directly measure the pelvises. However, the width between pin bones recorded high correlations with pelvic area (0.75, P<0.001). As this measurement can also be taken externally, more easily than internally, it seems that this parameter may be used as an indirect estimator of pelvic area in sheep and be used to cull ewes with small pelvic areas.

Keywords: Pelvic meter, pelvic dimensions, linear body measurements, Dorper rams

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Introduction

In sheep, a small pelvic area is associated with dystocia, which is a major cause of perinatal mortality and is associated with poor lifetime rearing performance of ewes (Haughey & Gray, 1982; Kilgour & Haughey, 1993; Hartwig, 2002). It would thus make sense to include pelvic area as a criterion to select breeding ewes; however its measuring *in vivo* poses some practical challenges due to the reduced size of sheep, when compared to cattle. As rams contribute 50% of the genetic make-up of their progeny and the heritability of pelvic area is medium to high (around 50-60%) in sheep (Kinne, 2002), indirect selection for improved perinatal lamb survival can be made by selecting rams with larger pelvic areas (Kilgour & Haughey, 1993). Besides being difficult to measure, there are no pelvic meters and well established techniques for sheep on the market. It would be of great practical value to find traits (i.e. external body measurement) highly correlated with pelvic measurements (height, width and area) or in the absence of these to develop a pelvic meter and measuring technique which are reasonably easy and accurate to use in sheep.

The aims of this study were thus to develop an instrument and a technique to measure the pelvises (height and width) of small stock and to investigate and quantify the correlations between pelvic measurements (height, width and area) and some external linear body measurements (body height, shoulder height, chest depth, forequarter width, hindquarter width, rump length, etc) in Dorper rams.

Materials and methods

All 272 Dorper rams participating in the 2009/10 Northern Cape veld-ram project (Niekerkshoop area) were used in this study. All the animals were managed extensively and performance tested under the same conditions on the veld between 6 and 13±1 months of age, receiving only a maintenance phosphate lick. The veld type covers most of Griqualand West region of sweet-mixed bushveld on rocky soil. The rainfall, occurring predominantly in summer, ranges from 250 mm to 350 mm/year, and is very erratic.

The rams were measured in July (mid-winter) and at the end of their growth testing period. A pelvic meter was developed specially for sheep in collaboration with the Science Park of the CUT (Central University of Technology, Free State). This instrument was pre-tested at the Bloemfontein abattoir on 90 randomly selected sheep prior to- and shortly after slaughtering. The correlation between the pre- and post- slaughter pelvic area was very high and significant (0.85; P <0.05).

To obtain the pelvic measurements, the rams were restrained by standing in a chute with light squeeze, faeces was removed from the rectum by gentle digital manipulation and the lubricated forceps of the instrument was carefully placed into the rectum (Deutscher, 1975). After inserting the pelvic meter into the animal's rectum, the forceps was opened while applying light pressure on its handle. The instrument was then slightly twisted from left to right while being inserted, so that the operator could feel the ossified joint on the *symphysis pubica*, to find the point to measure the pelvic height (PH, longest distance between the *pubic tubercle* on the floor of the pelvis and the sacrum on the pelvic roof). The instrument was then turned about 90° sideways at the same point (pelvic inlet at its widest point), to measure the pelvic width (PW, longest distance between the right and left *corpura ilii)*. After that, the instrument was carefully pulled out in the same twisted position to measure the width between the left and right *tuber ischii* (inside width between pin bones). The instrument was then thoroughly cleaned with a mild disinfectant solution after each animal was measured. The pelvic area of each animal was calculated as π (PH/2)*(PW/2) (Morrison *et al.*, 1986).

The following measurements were also taken as described by Fourie *et al*. (2002): rump length, shoulder height, body length, heart girth, chest depth, shoulder width, hindquarter width, the body weight following a 12-hour fasting period; scrotal circumference and body condition score (BCS, 1- 5 point scale). Additional measurements taken included: rump slope (angle). In addition, the distances (cm) between the pin bone and the *acetabulum* as well as between the *acetabulum,* and the *tuber coxae* were also measured. Analyses of variance were conducted to compare means of different parameters using GLM (General Linear Model) procedures of SAS (SAS, 1989). Product moment correlations between the variables were also calculated. A step-wise regression was done to estimate the relative contribution of each independent variable considered to the model, using pelvic area as the dependent variable.

Results and Discussions

The means for most variables considered in this study are depicted in Table 1, while Table 2 presents the correlation coefficients between pelvic and linear body measurements considered in this study. In general, the means for most variables considered were recorded, with the PH and PW of 13±1 month's old Dorper rams being very similar and PA recorded a relatively small variance.

Table 1 Mean ± standard deviation (s.d.) of pelvic and linear body measurements in Dorper rams.

Parameter	**Rams Mean ± s.d.**
Body length (cm)	71.2 ± 2.57
Shoulder width (cm)	22.9 ± 1.36
Chest depth (cm)	28.7 ± 2.49
Hindquarter width (cm)	24.1 ± 1.53
Shoulder height (cm)	64.1 ± 2.63
Rump slope (°)	34.2 ± 5.22
Rump length (cm)	23.4 ± 1.79
Pin bone to *acetabulum* (cm)	12.4 ± 1.49
Acetabulum to *tuber coxae* (cm)	14.1 ± 1.74
Heart girth (cm)	86.8 ± 3.70
Pelvic height (cm)	6.44 ± 0.42
Pelvic width (cm)	5.56 ± 0.37
Width between pin bones (cm)	5.14 ± 0.33
Body condition score	3 ± 0.67
Pelvic area (cm^2)	28.22 ± 3.21
Body weight (kg)	54.11 ± 5.41
Scrotal circumference (cm)	36 ± 2.32

In general, all pelvic measurements recorded very high correlations between each other and very low correlations with all other linear body measurements considered in this study.

Table 2 Phenotypic correlations between pelvic and body parameters in yearling Dorper rams

Parameter	**BL**	**SW**	**CD**	**HW**	**SH**	**RS**	**RL**	**HG**	**PW**	**WBP**	**PA**	**BW**
PH	0.23	0.09	0.10	0.09	0.25	0.04	0.15	0.22	0.48	0.42	0.86	0.25
PW	0.25	0.21	0.14	0.16	0.14	0.00	-0.02	0.22	-	0.86	0.87	0.30
WBP	0.25	0.25	0.17	0.15	0.14	0.03	-0.01	0.26	0.86	-	0.75	0.33
PA	0.28	0.17	0.14	0.14	0.23	0.02	0.07	0.25	0.87	0.75	-	0.33

Body length (BL), Shoulder width (SW), Chest depth (CD), Hindquarter width (HW), Shoulder height (SH), Rump slope (RS), Rump length (RL), Heart girth (HG), Pelvic height (PH), Pelvic width (PW), Pelvic area (PA), Width between pin bones (WBP) and Body weight (BW).

There is a high correlation (0.86, P <0.001) between pelvic area and pelvic height as well as between pelvic area and pelvic width (0.87, P <0.001). These correlations are understandably very high as pelvic height and pelvic width have a direct influence on pelvic area, being factors in the formula to calculate pelvic area. From these results (Table 2) it is also evident that there is a very high correlation between pelvic width and width between the pin bones (0.86, P <0.001) and a high correlation (0.75, P <0.001) between pelvic area and width between the pin bones. Therefore, it seems that the distance between the pin bones, a measurement that can also be taken externally, is a relatively good estimator for pelvic area in rams. The selection of rams with longer distances between pin bones should result in the selection of rams with larger pelvic areas.

Despite the fact that the Dorper breed standards emphasise wide hindquarters (for meat), very low correlations were recorded between hindquarter width and pelvic measurements (height, width and area). Similar results were found for all other rump measurements considered (Table 2). No comparable results were found in sheep-related literature, but in cattle Philipson (1976) and Dadati *et al.,* (1985) reported that a sloping rump was associated with calving ease). No comparable results were found in sheep related literature, but in cattle Philipson (1976) and Dadati (1985) reported that a sloping rump was associated with calving ease and shorter parturition periods in SA Mutton Merino ewes (Cloete *et al.*, 1998). Furthermore, a low correlation between BCS and pelvic area (0.10 P <0.10) was recorded, indicating that pelvic measurements were not affected by the condition of the animals.

Table 3 Partial contribution of different linear body measurements to pelvic area of Dorper rams

Parameter (n=270)	**Pelvic area π**
Age	0.1656
Shoulder height	0.0404
Scrotal circumference	0.0105
Body weight	NS
Body length	NS
Heart girth	NS
Chest depth	NS
Forequarter width	NS
Hindquarter width	NS
Rump length (cm)	NS
Pin bone to *acetabulum* (cm)	NS
Acetabulum to tuber *coxae* (cm)	NS
Rump slope (°)	NS
Body condition score	NS
Model R^2	0.2341

TC-PB = Distance from *tuber coxae* to the pin bone; PB-AC = Distance from pin bone to *acetabulum*; AC-TC = Distance from *acetabulum* to *tuber coxae*; WBP = Width between pin bones; SI = Selection index. Only variables with P <0.15 were selected by stepwise regression for the pelvic area model.

The stepwise regression analysis demonstrated that the combined contribution of all linear body measurements, considered in this model, on pelvic area in Dorper rams was only 0.23, indicating that there are other more important factors influencing pelvic area. The most important ones being pelvic related measurements (pelvic height, and width as well as distance between the pin bones).

Heritability of pelvic area of 50-60 % in sheep was reported by Kinne (2002), with pelvic height estimates being higher than pelvic width estimates, and pelvic area being more heritable than both height and width (Anderson & Bullock, 1994; Patterson & Herring, 1997). Therefore selection of sires with larger pelvic areas should result in female offspring with larger pelvic areas and reduced lambing difficulties.

Conclusions

Results of the present study indicated that the instrument and techniques developed in this study to obtain pelvic measurements in sheep are relatively easy to use and accurate. The correlations between pelvic measurements (internal measurements) and external body measurements are generally very low. These results further indicate the need to directly measure the pelvises of rams in order to calculate the pelvic area. However, the width between pin bones recorded high correlations with pelvic area. This measurement can also be taken externally more easily than internally and therefore it seems that this parameter may be used as an indirect estimator of pelvic area. As the heritability of pelvic area is relatively high and small pelvic area is a major contributor to dystocia, it makes sense to include pelvic area as a selection criterion for rams in an attempt to reduce dystocia in their female offspring.

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Addendum B

A questionnaire based survey: Farmers' opinion of the Dorper breed with regard to certain productive and functional traits.

Die Dorperskaaptelersgenootskap van Suid-Afrika
The Dorper Sheep Breeders' Society of South Africa
(Nrs 93/3253-98/3448 Certificate/Incorporation Nr 304 Reg. 62/98B-18)
Rasdirekteur/Breed Director: ***Mev/Mrs MC Milne***
(049 842 2241 Ê 049 842 3589 * Posbus/P.O. Box 26,
42 Van Reenen St, Middelburg EC/OK, 5900)

Questionnaire to Dorper Farmers

1 Are you farming just with Dorpers?

Yes	☐	No	☐		
Stud	☐	Commercial	☐	Both	☐

2 If no, what percentage of your flock?

80% +	☐	50%-79%	☐
20%-49%	☐	< 20%	☐

3 For how long have you been farming with Dorpers?

- Less than 5 years ☐
- 5-10 years ☐
- Longer than 10 years ☐

4 How has the hardiness of the Dorpers changed over the last years?

- Worsened significantly ☐
- Worsened ☐
- Remained the same ☐
- Improved ☐
- Improved significantly ☐

5 How did the fertility rate (Lambs marketed per 100 ewes mated) over the last 5 years changed?

- Worsened significantly ☐
- Worsened ☐
- Remained the same ☐
- Improved ☐
- Improved significantly ☐

6 How did the percentage of ewes that experienced lambing difficulty over the last 5 years changed?

- Worsened significantly ☐
- Worsened ☐
- Remained the same ☐
- Improved ☐
- Improved significantly ☐

7 At what age / weight do you mate your young ewes?

Age	:months
Weight:	:kg

8 Do you mate your young ewes with Dorper rams?

Yes	☐	No	☐

9 If no, what other race do you use?

____

____

10 Have you experienced sexual diseases in your herd over the last 5 years?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly
- None

11 Did the growth ability (come earlier into the market) improve?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly

12 How did the dressing percentage of your lambs change over the last 5 years?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly

13 How was the overall grading of your slaughter lambs over the last 5 years?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly

14 Did carcass weight of your lambs changed over the last five years?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly

15 Did the Dorper's walking ability change?
- Worsened significantly
- Worsened
- Remained the same
- Improved
- Improved significantly
- Uncertain

16 Do you prefer rams coming from a feedlot environment?
- Definitely yes
- Yes
- Not important
- No
- Under no circumstances

17 Do you prefer information on the growth performance of the ram?

- Definitely yes
- Yes
- Not important
- No
- Under no circumstances

18 Do you prefer information on the production performance of the ram's mother?

- Definitely yes
- Yes
- Not important
- No
- Under no circumstances

19 Do you think that the modern Dorper has enough body fat?

Yes ☐ No ☐

20 In which Province of South Africa do you farm?

- Free State
- Kwazulu Natal
- Limpopo
- North West
- Gauteng
- Northern Cape
- Eastern Cape
- Western Cape
- Mpumalanga
- Namibia
- Botswana

Coding

1	Yes	1
	No	2
	Stud	red
	Commercial	black
	Both	red
2	80% +	80
	50%-79%	65
	20%-49%	37
	< 20%	10
3	Less than 5 years	2.5
	5-10 years	7
	Longer than 10 years	10
4	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
5	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
6	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
7A	Age:	Average age
7B	Weight	Average weight
8	Yes	1
	No	2
9	Damara	1
	Van Rooy	2
	Swartkop Persian	3
10	Worsened significantly	5
	Worsened	4

	Remained the same	3
	Improved	2
	Improved significantly	1
	None	0
11	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
12	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
13	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
14	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
15	Worsened significantly	5
	Worsened	4
	Remained the same	3
	Improved	2
	Improved significantly	1
	Uncertain	0
16	Definitely yes	5
	Yes	4
	Not important	3
	No	2
	Under no circumstances	1
17	Definitely yes	5
	Yes	4
	Not important	3
	No	2
	Under no circumstances	1

18	Definitely yes	5
	Yes	4
	Not important	3
	No	2
	Under no circumstances	1
19	Yes	1
	No	2
20	Free State	11
	Kwazulu Natal	10
	Limpopo	9
	North West	8
	Gauteng	7
	Northern Cape	6
	Eastern Cape	5
	Western Cape	4
	Mpumalanga	3
	Namibia	2
	Botswana	1