USING PELVIC AREA MEASUREMENTS IN THE SELECTION OF REPLACEMENT SUSSEX HEIFERS

by

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Declaration of independent work

I, Lubabalo Bila, do hereby declare that this research project submitted for the degree of Master of Agriculture, is my own independent work and has to the best of my knowledge not been submitted before to any institution by me or anyone else as part of any qualification. It complies with the code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State.

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(Study leader)

Dedication

I dedicate this work to the loving and living memory of my grandparents, Nontlantsi and Mthonjeni Bila. I also dedicate this to the loving memories of my late high school Agricultural Science teacher, Nolizwe Qwase and my dear friend, Bhekisizwe Ntuli, who have both passed on. You will remain forever in our hearts.

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List of abbreviations

BCS	Body Condition Score
BL	Body Length
BW	Birth Weight
CCA & NFACC	Canadian Cattlemen's Association & National Farm Animal Care Council
CES	Calving Ease Score
CD	Chest Depth
CM	Conformation
DA	Discriminant Analysis
DAFF	Department of Agriculture, Forestry and Fisheries
EBVs	Estimated Breeding Values
EC	Eastern Cape
EPDs	Expected Progeny Differences
FAO	Food and Agricultural Organization of the United Nation
FPD	Feto Pelvic Disproportion
GDP	Gross Domestic Product
HH	Hindquarters Height
HW	Hindquarters Width
ICP	Inter Calving Period
ISRDS	Integrated Sustainable Rural Development Strategy
KG	Kilograms
LW	Live Weight
PA	Pelvic Area
PCA	Principle Component Analysis
PH	Pelvic Height
PW	Pelvic Width
RA	Regression Analysis
RDP	Rumen Degradable Protein
RE	Rhys Evans Group Farm
RFM	Retained Fetal Membrane
RL	Rump Length
RMRD	Raw Milk Reception Dock

RPO	Red Meat Producers Organization of South Africa
RS	Rump Slope
SA	South Africa
SW	Shoulder Width
SPSS	Statistical Package for the Social Sciences
TD	Transverse Diameter
VD	Vertical Diameter

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ABSTRACT

USING PELVIC AREA MEASUREMENTS IN THE SELECTION OF REPLACEMENT SUSSEX HEIFERS

The aim of this study was to use pelvic area measurements and external body measurements in the selection of replacement Sussex heifers to reduce dystocia during parturition, while improving their ease of calving. A total number of one hundred and eighty-six (186) first calf Sussex heifers *ca* 24 months old, weighing approximately 350 kg were used for this study. All heifers used for the study had a good body condition score (BCS) with an average of three and weighed more than 65% of the mature female body weight of the Sussex breed. Six two-year-old bulls, weighing approximately 800 kg were used for mating the 135 heifers during the first trial and with a bull ratio of (1:35; 1:35; 1:35 and 1:30). The second trial consisted of 51 heifers with a bull ratio of 1:30 and 1:21. All the bulls were tested for fertility by a private veterinarian before the breeding season. A phenotypic negative correlation was found between CES and PA, r = -0.26 and a moderate negative correlation between CES and PH, r = -0.40. There was a significant correlation between CES and calf gender, r = -0.35. The chances of a heifer to experience dystocia were more when a male calf was born compared to female calves. Birth weight, which is regarded as a good indicator of calf size revealed a positive correlation with CES, r = 0.31, this showing that the higher the BW, the higher the probability of a heifer to experience dystocia. The R2 value of 0.34 indicated that approximately 34% of the variability in PA could be predicted by the chest depth of heifers. It can be concluded that pelvic measurements in Sussex heifers may be a valuable tool to reduce dystocia.

Keywords: Body measurements, dystocia, calving ease, pelvic dimensions

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

Beef cattle production is the most important livestock subsector in South Africa (SA). It contributes about 25-30% of the total agricultural output per annum (Musemwa *et al*., 2008). Cattle meet the multiple objectives that are desired by resource-poor farmers in the country. These include the provision of draught power, manure, cash sales, and other socio-economic functions (Shackleton *et al*., 1999; Chimonyo *et al*., 1999; Dovie *et al*., 2006). Unpredictable rainfall and high incidence of droughts in most communal areas of SA, particularly in the Eastern Cape (EC) Province influence the majority of the resource-poor farmers who depend on livestock for their livelihoods.

South Africa is partially a marginal agricultural country, where agriculture contributes more or less 3% of the Gross Domestic Product (GDP) and approximately 7% to formal employment, whilst the agro-industrial sector comprises about 12% of SA GDP (Musemwa *et al*., 2008). Agriculture has contributed an average of about 6.5% of SA's total exports. Exports have increased from 5% in 1999 to 46% in 2009 for agricultural products. Livestock farming has a great potential to alleviate household food insecurity and poverty in communal areas of SA (Integrated Sustainable Rural Development Strategy, 2004; Coetzee *et al*., 2004).

Although livestock thrives well in marginalized environments, the market off-take rate is very low. Off-take rates of between five and ten percent have been reported, compared to 25% in the commercial sector (Nkhori, 2004). Reproduction is the main factor limiting production efficiency of beef cattle. As the world population rises, the demand for meat products continue to escalate in almost all regions of the globe, especially in developing countries (Delgado, 2003). In SA, total meat consumption is estimated at 41.0 kilogram (kg) per head per year, which is the second highest in Africa (after Ghana) and closely mirrors the global meat consumption estimates of 41.2 kg per head per year (Food and Agricultural Organization of the United Nation, 2009; Taljaard *et al*., 2006).

The SA commercial livestock sector comprises of approximately 35,000 farmers, of which 2,500 are seed stock producers (Red Meat Producers Organization of South Africa, 2011). The informal sector includes 240,000 emerging farmers, of which 87,000 have the ability or potential to join the commercial sector. In addition to this, there are approximately 3 million subsistence farmers (Department of Agriculture, Forestry and Fisheries, 2010). Due to several factors, including environmental concerns, the national beef herd cannot realistically be increased, and therefore it is of utmost importance to improve existing production efficiency in SA (De Jong & Phillips, 2013).

The SA red meat sector contributed 14.8% to the total gross value of agricultural production during the 2008 to 2009 season, with cattle being the main contributor at 10.1%, while sheep contributed 2.5% in the same period (DAFF, 2010). During a 12-year period (1998-2010), the contribution of livestock to the total gross value of agricultural production has increased from approximately 40% to nearly 50% (Raw Milk Reception Dock, 2012). In SA, the gross value of beef production is dependent mainly on the total number of cattle slaughtered at abattoirs and the prices received by producers from abattoirs. The average gross value of beef produced during the period 2005/06 until 2014/15 amounted to R16, 668,752,000 (DAFF, 2016).

Dystocia is defined as prolonged or difficult parturition and it is a condition in which the first or, especially the second stage of parturition was markedly prolonged for more than six hours and the cow will require assistance (Abdela & Ahmed, 2016). Dystocia affects the profitability of herds, animal welfare, and acceptability of the production system by the consumer (Carnier *et al*., 2000). Dystocia (birth difficulty) 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). Measuring the pelvic area (PA) is becoming a very vital part of the herd management for most breeding animals in SA, and it should become the basis for selecting female breeders, especially in the beef cattle industry (Van Der Merwe, 2017).

Deutscher (1991) indicated that the major cause of dystocia is a disproportion between the offspring's birth weight (BW) and the dam's PA. These findings were also supported by Cook and Tess (1993), and Troxel (2008). Dystocia results in increased calf mortality (Mee, 2008; Damatawewa & Berger, 1997) and lowers postpartum conception in cows (Mee, 2008). Heifer's age and calf BW have been shown to be the most important factors influencing dystocia. Calves that are born during dystocia reach lower weaning weights and are more susceptible to diseases (Walker *et al*., 1992).

PA has been seen as a reliable measurement influencing calving difficulty, as larger PA is associated with reduced calving difficulty (Murray *et al*., 2002) and it is used to identify potential problem heifers with small pelvic sizes (Micke *et al*., 2010) that may be at risk for dystocia at calving. Reproduction efficiency in the beef cattle industry is affected by fertility, limited grazing land for herd expansion, environmental factors like climate change and breed adaptability. Other factors include nutrition, genetic factors, animal health, diseases, lack of skills in the farming sector, stock theft and mortality, which is mostly caused by dystocia and poor management in farms. Dystocia is one of the reproductive health problems that cause considerable economic loss in the beef industry all over the world.

Mellor & Diesch (2006) reported that larger cows have larger pelvic openings and have higher BW. It appears that selection for the size of dam alone as a means of reducing calving difficulty may be ineffective because of a correlated response in the size of the fetus (Heringstad *et al*., 2007; Rushen *et al*., 2008). Deutscher *et al*. (1991) also found that PA is the most reliable yearling trait indicating potential calving difficulty and has the most influence on dystocia of all cow measurements. A disproportionally large calf size at birth in relation to the mother's PA is one of the biggest causes of dystocia (Briedenhann, 2010). Pelvic size measured as PA is inversely proportional to the occurrence of dystocia in heifers (Nogalski, 2003).

Selecting heifers with a larger pelvic size, rather than by body weight alone, should be advantageous and should not increase birth weight (Deutscher *et al*., 1991). This problem is receiving increased attention by the beef cattle industry because of the utilization of some of the large bull or sire breeds in crossbreeding programmes. A small pelvic opening is one of the core factors that increases the chances of dystocia in the beef cattle industry. PA is commonly calculated by multiplying the pelvic height (PH) with the pelvic width (PW), which results in a rectangular area (Kolkman *et al.*, 2009; Nogalski, 2003). PA measurements are not done in most herds, since measuring PA is an operation that requires skill and suitable equipment that the farmer does not always have (Van Rooyen *et al.*, 2012).

In order of descending financial importance, dystocia impacts production (41% of the cost), fertility (34%) and cow-calf morbidity and mortality (25%), excluding costs associated with culling, veterinary costs and other management costs (Mee, 2008). In addition to the effects of dystocia on cow culling mortality (Mee, 2008) and stillbirth, dystocia increases the likelihood of therapy in both cow and calf respiratory and digestive disorders, as well as retained placenta, uterine diseases, mastitis and hypocalcaemia (Lombard *et al*., 2007).

Losses during the perinatal period may contribute up to 80% of total calf deaths. Up to 60% of perinatal deaths could be attributed to stressful birth (Cloete *et al.*, 1998). Pelvic size heritability of 50%-60% was found in sheep (Kinne, 2002) and 36%-92% in beef bulls (Deutscher, 1991). Therefore, selecting rams and bulls 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. Although researchers agreed that BW is the most important measurable trait affecting or 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).

1.2 Problem statement

South African farmers are experiencing vast problems with dystocia, which is of economic importance in the beef cattle industry, as it is a major cause of calf mortality (Mee, 2008; Grohn & Rajala-Schultz, 2000). This problem is receiving increased attention in the beef cattle industry where large sire breeds are increasingly used in crossbreeding programmes. Although the Sussex breed perform extremely well in good veld conditions in SA, it is one of the cattle breeds that experiences dystocia the most in the country, especially heifers (Gerhard, 2017).

Dystocia has a negative impact on many farms in SA, because cows and calves die during the parturition process. It is an undesirable reproductive event resulting in an increased risk of calf morbidity, mortality, reduced fertility as well as cow survival and it consequently reduces farm profitability on livestock farming (Abdela & Ahmed, 2016). Moreover, dystocia may have some negative effects on reproductive performance, causing stillbirth, cow death, retained placenta, uterine infections, or increased involuntary culling, which have negative consequences for farm economics as well as for cow welfare (Abdela & Ahmed, 2016).

Selecting heifers and bulls with increased pelvic size should ideally increase pelvic size in the female progeny, resulting in decreasing chances of dystocia, morbidity and mortality in the herd. The pelvic bone is a genetic factor that can be inherited from both parents. Thus, it is significant to consider PA measurements during the selection process, as the genes will be passed from one generation to the next (Heringstad *et al.*, 2007).

According to Briedenhann (2010), PW is more important in *Bos taurus* cattle, while PH is more important in *Bos indicus* cattle. Dystocia affect the economy of all herds negatively, because cows and calves die before marketing age, and it increases labour and veterinary costs, resulting in lower reproduction and milk production in cows (Patterson & Herring, 1997; Hartwig, 2002). It has been stated that there is little information on the effects of calving difficulty on subsequent reproductive performance of the cow (Mee, 2008). SA farmers are very concerned and interested in finding out more regarding fundamental strategies that can be implemented to cut these unnecessary costs. The question that arises is whether pelvic measurements and the selection for larger PA will reduce dystocia in perspective of calving ease.

1.3 Rationale/motivation

This study will shed light on the relationship the between external body measurements, PA measurements and dystocia in Sussex heifers, and on the influence of other factors on dystocia. The information that will be attained from this study will be freely accessible and available at all times to all farmers, breeders, students, researchers and other people that will be in need thereof.

It has been suggested that selection based on PA and body weight together might be useful in protecting against calving difficulties (Nogalski, 2003). The heritability of PA and the genetic relationships between PA and other performance characteristics such as BW, rump slope (RS) and rump length (RL) must be known before the trait can be utilized to improve production efficiency. PA is more heritable than PW or PH (Boyles, 2000). Dystocia is mostly common in sheep, and it causes death in many lambs and ewes (Hartwig, 2002).

Size of the calf at birth is measured by BW, which is a function of several genetic and environmental factors such as sex, length of gestation, breed, heterosis, inbreeding, genotype, age, parity of dam and nutrition of the dam (Mee, 2008). The size of the dam is measured by weight, and it is influenced by genetics and environmental factors. However, the size of the dam is measured by weight, and it has not been a good predictor of calving problems. 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; Mee, 2008). Animals with extreme dystocia produce less milk than animals with no dystocia (Grohn & Rajala-Schultz, 2000). According to Abdela & Ahmed (2016), dystocia can result from other causes that interfere with the expulsive forces needed to expel the calf. This includes lack of uterine contractions (weak labour), and incomplete dilation of the cervix and vagina due to stenosis and uterine torsion.

1.4 Aim and objectives

Aim

The aim of this study is to use pelvic area measurements and external body measurement in the selection of replacement Sussex heifers to reduce dystocia amongst heifers at parturition, while improving their ease of calving.

Objectives:

- ✓ To determine the relationship between pelvic area, pelvic dimensions and dystocia.
- ✓ To evaluate the relationship between pelvic dimensions and body measurements (pre-breeding) in predicting dystocia in two-year-old heifers.
- ✓ To evaluate the effectiveness of pelvic measurements in predicting dystocia in two-year-old heifers.

1.5 Research hypothesis

The use of pelvic area and external body measurements during selection will reduce the occurrence of dystocia.

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CHAPTER TWO

LITERATURE REVIEW

2.1.1 Introduction

This chapter reviews the impact of using PA measurements to select replacement Sussex heifers in SA, and beyond the country. It also explains the origin and history of the Sussex breed, dystocia, welfare, environmental factors and body measurements. Factors that may contribute to dystocia in heifers like age of dam, targeted weight, calf birth weight, dam's pelvic area, gestation length, body condition of heifers, position and presentation of the calf in the uterus, sire selection, fertility and feeding are discussed here. Additionally, the importance of pelvic measurements, the factors that influence dystocia and prevention of dystocia as well as financial loses that may occur due to dystocia are also discussed. Finally, it is explored how dystocia is perceived in other countries, and how they have adapted to it.

2.1.2 Background

According to Smith (2005), the growth in pelvic height (PH) and pelvic width (PW) differs between beef heifers of different frame sizes. Briedenhann (2010) states that PW is more important in *Bos taurus* cattle, while PH is more important in *Bos indicus* cattle. It seems that in sheep, PW has a greater effect on pelvic area (PA) than PH (i.e. 0.94 vs. 0.84, respectively). This is in contrast to what was earlier reported for beef heifers, in which differences in PA were usually attributed to differences in PH (Patterson & Herring, 1997).

No similar studies for sheep could be found by the authors to compare results. Johanson & Berger (2003) reported that rump slope (RS) in cattle has no influence on internal pelvic measurements or calving ease. According to Johanson & Berger (2003), a disproportionate difference between foetus size and dam size is the major cause of dystocia. However, Mee (2008) reported that in cattle, a sloping rump (subjectively scored) 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 seen whether phenotypic selection pressure for conformation and type (flat rump, hind quarter width and muscling.) has indirectly affected pelvic measurements and ease of lambing in Dorper ewes.

Research studies indicate that calf BW in relation to the cow's PA determines the degree of calving difficulty. Standard PA and calf BW ratios have been developed by dividing the heifer's PA by her calf's BW. PA measurements obtained on a heifer before breeding or at the time of pregnancy are divided by these standard ratios to estimate the calf BW, and whether she can deliver without having substantial calving difficulty. If the measurements are obtained before breeding, sires that will produce offspring with the estimated deliverable BW can be selected (Mellor & Diesch, 2006).

Rushen *et al.* (2008) stated that even though heifers and young cows produce calves with lighter BW, this does not necessarily result in less dystocia. In affirmation, Mellor & Diesch (2006) reported that dystocia in two-year-old cows was approximately 36% higher than in three-year-old, and 45% higher than in four- and five-year-old cows. Also, Brinks *et al*. (1973) have indicated that two-year-old dams experienced the most dystocia of any age group. PA has been shown to be inversely related to the occurrence of dystocia in beef heifers (Le Gal *et al.*, 2010).

All the factors affecting dystocia that can be attributed to the dam and pelvic size has ranked first in importance in most regression analysis (RA) studies (Deutscher *et al.*, 1999; Chassagne *et al*, 1999). One exception to this is the study of Basarab *et al.* (1993), who also used both regression analysis (RA) and discriminant analysis (DA) for predicting dystocia. In that study, yearling PH was of no value for prediction of dystocia and accounted for only five percent of the explained variation in calving difficulty.

There is little information in the literature concerning the genetic influences within the breeds on PA (Mee, 2008). The heritability of PA and the genetic relationships between PA and other performance characteristics (parameters) must be known before the trait can be utilized to improve production efficiency. Other researchers have also reported these effects (Mee, 2008; Rushen *et al.*, 2008). Increasing feed intake or body condition of the dam to a very high level before calving, have been shown to increase calving difficulty or calf losses (Noakes *et al*., 2001; Sorge, 2005; Mee, 2008).

However, the effects shown by these researchers were high feed levels increases fat deposition on the dam, resulting in a subsequent reduction of the size of the birth canal, and not through increased calf birth weight. There were no beneficial effects of low pre-calving feed levels on calving difficulty, whilst distinct detrimental effects on subsequent reproduction were reported.

This is substantiated by significant genetic variation in the shape of milk lactation profiles previously reported in dairy cows by Berry *et al*. (2003) and is further substantiated by the delayed interval to peak milk yield in cows following a difficult calving. This indicates that cows try to reach their genetic potential although their attempt may be delayed.

Despite the inclusion of calf weight in the multiple regression model, the sex of the calf still had a significant effect on the likelihood of dystocia. This also is in agreement with the report of Johanson & Berger (2003). This indicates, therefore, that differences between calf sex other than birth weight (most likely morphological) influence dystocia. Incompatibility between the size of the calf and pelvic opening of the dam has also been reported to be associated with dystocia (Johanson & Berger, 2003).

The major problems that have direct impacts on reproductive performance of dairy cows are abortion, dystocia, retained fetal membrane (RFM), metritis, prolapse (uterine and vagina), anestrus and repeat breeding. These could be classified as pre-partum and post-partum reproductive problems (Shiferaw *et al*., 2005; Lobago *et al*., 2006). Dystocia is a welfare problem of cows and calves and is also of economic importance. It causes pain and injury to the cow. Therefore, it directly leads to poor welfare in cows. Moreover, dystocia may have negative effects on milk yield and reproductive performance, causing stillbirth, cow death, retained placenta, uterine infections or increased involuntary culling (Kaya *et al*., 2015).

Some studies conducted in different parts of Ethiopia indicated that 26.5% of cows examined had at least one of these reproductive problems in and around Bedelle South West Ethiopia (Bitew & Prased, 2011), and retrospective analysis of clinical data in central Ethiopia showed 44.3% of the cows had major pre-partum and post-partum reproductive problems (Hadush *et al*., 2013). Gashaw *et al*. (2011), Dawit & Ahmed (2013) also reported the prevalence of 33.59% and 40.25% of reproductive health problems of cows in Jimma town, south-west Ethiopia and Kombolcha, north-east Ethiopia, respectively.

2.1.3 Origin and distribution of Sussex Breed

Sussex cattle are a red breed of beef cattle from the Weald of Sussex, Surrey and Kent in South Eastern England. Descended from the draught oxen long used, they were selectively bred from the late 18th century to form a modern beef breed, which is now used in many countries around the world (Fussel, 1952). They have a thin summer coat and many sweat glands, but grow a thick coat in winter, so they are suited to both hot summers and cold winters. They have a docile temperament but can be very stubborn. Polled and horned strains of the breed are available all over the world, including SA (Annelie, 2014). The Sussex breed has spread across the globe and they are considered as a rare breed because of their low numbers. Sussex cows can weigh approximately 585kg (Cornwall, 1954a).

Their good genetic traits are easily passed on to their progeny, especially when crossbred with other breeds that need to improve their beefing ability and thriftiness (Annelie, 2014). Calves weigh about 30-40kg at birth. Sussex cattle remain fertile and can keep reproducing to an old age. Additionally, they can calve regularly under commercial conditions. Sussex cattle mature early and have plenty of muscling (Annelie, 2014). Their carcasses have high levels of saleable meat, and the beef is tender and flavoursome. Sussex bulls show strong masculine character with a blocky, medium-size frame. Bulls generally weigh 800 kg and above at two years old, to approximately1000 kg when mature. They thrive in both hot and cool climatic conditions, and are relatively early maturing (Cornwall, 1954b).

Sussex bulls are adaptable and able to walk long distances in the dry extensive areas of the country. The most important characteristics defining the role of Sussex bull in the market are their pre-potency, hardiness, good weaning weights and excellent post weaning growth (Annelie, 2014). Both horned and polled bulls are now bred in SA (Annelie, 2014). Having evolved from poor pasture in the past, the ability to subsist in poor grazing conditions has been retained. Due to their even, dark brown colouring, no pigmentation problems are experienced. Sussex bulls have good depth and capacity, which ensures a well-balanced conformation in general. This, together with a calm temperament, good muscling and finishing characteristics all result in an ideal beef breed (Annelie, 2014).

Structural traits in cattle tend to be highly heritable, and PA is no exception. This means there is a large genetic influence on PA, which results in rapid response to selection. However, PA is genetically correlated with many other traits, so selection for increased PA alone can result in other traits changing for the worse. For example, selecting for increased PA can result in increased birth weight and mature weight. Pelvic measurements can be taken prior to the first breeding season and combined with a reproductive tract examination (Kolkman *et al*., 2009).

Figure 2. 1: A picture of the Sussex heifer (A) and bull (B) (Retrieved from internet on 10 April 2019)

The economic importance of the biological traits included in a breeding objective is usually assessed by their economic weights, which can be defined as the expected increase in herd annual profit resulting from a unit increase in a trait due to selection (Jorge Júnior *et al.*, 2007). In the case of low-input beef cattle smallholders, which represent about 40,000 families in the southern half of Rio Grande do Sul, the identification of objectives should be based on the production systems adopted and market shared by this segment of producers, given that family-based operations have their own features and do not necessarily follow the technological model of modern beef cattle industry (Ribeiro, 2003).

In addition, the genetic improvement of low input cattle from smallholders must be treated differently from traditional elite seed stock breeding programs, considering, besides environmental production system and market aspects, their cultural way of life and production (Laske *et al.,* 2009). Easily obtained traits with few measurements during the life of the animals should be emphasized.

2.1.4 Dystocia (Birth difficulty)

Animal scientists believe that calving difficulty results from breeding heifers at an incredibly young age. However, according to (Kroker *et al*., 2000), calving difficulty is a problem of first-calf heifers, whether they calve for the first time at two years or three years. Well grown two-year- old should have no more difficulty to calf than three-year-old heifers, despite the more mature frame of three-year-old heifers.

This is usually due to the fact that calf size increases with the increased frame size of the dam, and the fact that older heifers tend to be fatter at calving, both of which can lead to calving difficulties. This statement is in contrast with the results of Van der Merwe & Schoeman (1995), who concluded that calving difficulties (dystocia) in extensively managed Simmentaler heifers differed (*P* <0.01) between heifers calving at 24 months and heifers calving at 36 months. They found the factors contributing to calving difficulties to be the weight of the heifer at breeding, birth weight and sex of the calf (Van der Merwe & Schoeman 1995). Pelvic size in the heifers was, however, not important (*P* >0.05). Heifers that experienced calving difficulty weighed on average 8.7% less and gave birth to calves which weighed on average 8.9% more than the heifers which did not experience calving difficulty. Although early mating of Simmentaler heifers resulted in an increased number of calves born and weaned, lifetime productivity was not significantly influenced.

It would seem as if early calving had a detrimental effect on calving ease and calf survival rate. It was further concluded that early breeding of extensively managed Simmentaler heifers should not be considered as a standard management practice. It would seem unlikely that such a system can improve in the traditional system on natural pasture. The system was not even self-maintaining (Van der Merwe & Schoeman, 1995). In indigenous breeds, however, calving problems in early calving heifers may be of less concern (Scholtz *et al*., 1991; Lepen *et al*., 1993).

Pelvic size, independent of cow weight, affects calving difficulty. Heifers with increased skeletal size usually have larger pelvic openings, but also tend to have heavier calves at birth. Hence, selection for cow size alone is ineffective (David *et al*., 2017). Calving ease will continue to be an important consideration as the industry produces fast-growing muscular progeny by terminal sires. These sires should be selected on measures of direct calving ease by using expected progeny differences (EPDs) values for calving ease and birth weight.

Calving ease is one of the most economically significant secondary traits (Dekkers, 1994; Dematawewa *et al.*, 1997), especially for first-calf heifers. It measures the presence or absence of dystocia and its intensity. Dystocia can negatively affect reproductive traits, such as days open or the number of services per pregnancy (Dematawewa *et al*., 1997). Difficult births increase direct costs of the herd (veterinary fees, calf or cow death or both, and extra farmer labor), as well as indirect costs, such as an increase in the risk of subsequent unfavorable health events, an increase in culling rate, and a reduction in yield (Dekkers, 1994; Dematawewa *et al*., 1997).

Dystocia is a leading cause of calf death at or shortly after birth and leads to uterine infections, more retained placentas, and longer calving intervals. It has been estimated that between two and 23% of cows in a herd experience difficulty in calving that require farmer or veterinarian assistance (Mee, 2008). The various factors affecting dystocia in cattle include mal-presentations and uterine torsion, calf birth weight, multiple calving's, perinatal mortality, cow pelvic area, cow body weight, body condition at calving, and gestation length, cow age and parity, the year and season of calving, the place of calving, maintenance practices, disorders, nutrition, and the calf sex (Zaborski *et al*., 2009).

Since genetic selection could improve calving performance, it is important to include calving traits such as dystocia, in genetic evaluations (Eaglen *et al*., 2012). Although reducing dystocia rates by breeding is a slow process because of the low heritability, low estimates of heritability for dystocia means that most of the variation for this trait can be attributed to environmental or management factors, and much data is needed to obtain sufficiently accurate estimates that have an impact on selection indices (Eriksson *et al*., 2004).

Pelvic measurements should be used in addition to, not in place of selection for size, weight, and above all, fertility. Producers should be aware that selection for PA is likely to result in increased size of the entire skeleton and animal. Increased skeletal size of the dam will be reflected in higher birth weight and dimensions of the calf. Pelvic measurements, on the other hand, can be used to successfully identify abnormally small or abnormally shaped pelvises (Kolkman *et al*., 2009). These situations, if left unidentified, are often associated with extreme dystocia, resulting in Cesarean delivery and even death of the calf or cow. Pelvic measurements can be obtained with a Rice Pelvic meter, manufactured by Lane Manufacturing, 2075 South Valencia, Unit C, Denver, CO 80231.

An experienced technician may obtain PA measurements. It is important that the person doing the measuring have a thorough understanding of the birth canal, pelvic structure, and reproductive tract. Practice and experience are necessary before accurate measurements can be attained. Measurements of the pelvis by the Rice pelvic meter is accurate when compared to carcass measurements (Kolkman *et al*., 2009), and moderately repeatable between and within veterinarians (Van Donkersgoed *et al*., 1993). A latter report in 2011 by Citek and co-workers suggested that breed differences in pelvic conformation support the use of PA rather than transverse diameter of the pelvis (TD) or vertical diameter of the pelvis (VD) for application of pelvic measures across breeds.

2.1.5 Welfare

Pelvimetry is the measurement of the capacity and diameter of the pelvis, either internally or externally or both, with hands or with a pelvic meter (Blood *et al.*, 2007). The issue of animal welfare when internal pelvimetry is conducted has been brought up due to it being an invasive procedure that has a risk of damaging rectal mucosa (Murray *et al*., 2002). Additionally, the usage of epidural anaesthesia to reduce arched backs and straining when measurements are taken requires special training whereas, external pelvimetry needs neither specialized equipment not training. In the author's opinion, there is an inherent risk for injury but internal pelvimetry done properly, gently, and with adequate lubrication can prevent damage to the rectal mucosa.

2.1.6 Environmental factors

Temperature has been shown to have a significant impact on calf birth weight. Although using sires with low birth weight, EPDs may reduce some calving problems, whilst environmental factors are responsible for approximately 55% of calving difficulties (Deutscher *et al*., 1999). EPDs provide estimates of the genetic value of an animal as a parent. Specifically, differences in EPDs between two individuals of the same breed predict differences in performance between their future offspring when each is mated to animals of the same average genetic merit. EPDs are calculated for birth, growth, maternal, and carcass traits, and are reported in the same units of measurement as the trait.

Calf birth weights can vary significantly from year to year even though the same genetics and management are used. Uematsu *et al*. (2013), have shown that calves born in the summer seasons weigh less than calves born in the winter and spring months. As a result of that calves born in winter were more prone to dystocia compared to other seasons (Uematsu *et al*., 2013).

The increase in foetal weight during the cooler winter months is most likely because of increased nutrient intake from supplemental feeding by the cow. As the nutrient intake increases, nutrient flow to the foetus increases, which can result in increased growth rate. A long-term study was conducted at the University of Nebraska to determine the effects of temperature on calf birth weight (Deutscher *et al*., 1999). In their study Deutscher *et al*. (1999) revealed that there is a significant difference (P <0.05) in birth weights among years or seasons. In general, calf birth weight decreased as winter temperatures increases. The results showed a negative linear relationship between winter temperature and calf BW.

First-calf heifers account for the majority of calving difficulty (Anderson, 1992). This is true despite the fact that most first-calf heifers are observed more closely and assisted more readily at calving than mature cows. While this will come as no surprise to cow or calf producers, this information can be useful. High rates of dystocia among first calf heifers and young cows are mostly because they are smaller at first parturition than at subsequent calvings, but other factors may contribute. Among these are the fact that the pelvic opening changes slightly in shape as the first calf is born (Anderson, 1992).

2.1.7 Body measurements

Objective body measurements can be a useful tool to aid selection. Some common phenotypic measurements in cattle include back-fat, height at the shoulder, height at the hips, length of body, depth of body, scrotal circumference, skin thickness, rump length and pelvic size. Linear body measurements are helpful in matching mature animal size to production resources. 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 (Fourie *et al*., 2002).

Body weight in sheep is an important indicator of growth, but it 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 in sheep (Fourie *et al.*, 2002). According to Greyling & Taylor (1999), high significant correlations (P <0.01) were obtained for body length and shoulder height (r = 0.86), shoulder width (r = 0.80), body weight (r = 0.92) and scrotal circumference (r = 0.86). Most body measurements are associated with bone growth (Greyling & Taylor, 1999).

Parameters such as 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). These authors also stated that measuring the PA of the dam to predict dystocia has once again become popular as a tool in selecting replacement heifers, even though PA 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 PA measurements, when examined during pregnancy, than those without calving difficulty (Van Donkersgoed *et al.*, 1990). The authors also found that heifers with calving difficulty had significantly (P <0.0001) heavier calves at birth than those without calving difficulty.

2.2 Factors that can influence the occurrence in dystocia in heifers

2.2.1 Age of dam

The age at which beef heifers should be first bred therefore, depends upon the economics of management input against returns (Kroker *et al*., 2000). Heifers cannot be bred early unless they reach puberty prior to, or early in their first breeding season. Puberty in heifers can be characterized in several ways including age at first ovulation, age at first oestrus, and age at which a heifer can support pregnancy without any difficulty (Ahmadzadeh *et al*., 2011).

High birth weights have been associated with increased dystocia in ewes bearing single lambs. As noted by Anderson (1992) and Hartwig (2002), young ewes are more susceptible to lambing problems than mature ewes that have lambed previously. During the first mating heifer should weigh a minimum live weight of 65% above the cow matured breed average weight.

2.2.2 Targeted weight

In several studies, early mated heifers need preferential nutritional treatment which means that the main cost of breeding heifers as yearlings is the need to feed weaner heifers so that they achieve a minimum required live weight at breeding (Lepen *et al*., 1993). Target weight is considered to be the threshold weight for puberty, and thus, the onset of oestrus in heifers (Kroker *et al*., 2000; Hall, 2005a). Below this weight, growth rate and nutrition are the limiting

factors to the onset of puberty. Above this weight, the maturation rate of the reproductive tract, as well as genetics are the limiting factors to puberty.
Another study by Hall (2005b) reiterated that heifers raised on low energy diets are delayed in reaching puberty, and have lower pregnancy rates in their first breeding season than heifers raised on a high energy diet. The target weight principle calls for feeding heifers to a pre-breeding target weight that represents 65% of the heifer's projected mature weight (Patterson *et al*., 2005a). When heifers are developed to reach approximately 65% of their mature weight by 12 to 13 months of age, puberty is not restricted by nutrition (Hall, 2005b).

In contrast to the above statement, Hall (1997) had earlier revealed that feeding heifers' excess energy to reach 65% of mature weight prior to 12 months of age does not initiate puberty, but increases body fat percentage at puberty in rapidly developed heifers. Puberty can be expected to occur at a genetically predetermined size among individual animals (Patterson *et al*., 2005), and only when heifers reach genetically predetermined target weights can high pregnancy rates be obtained. The genotype of the heifer must be considered in the development program (Patterson *et al*., 2005).

When heifers are fed to achieve appropriate weights prior to first breeding, a positive effect on re-breeding after the first calf can be seen. When heifers are bred for the first time with inadequate live weights, conception rates and calving percentages are poor, calving problems increase and their chances of being re-bred while, nursing their first calves are very low (Kroker *et al*., 2000).

2.2.3 Calf birth weight

According to Heins *et al*. (2010) the breed, year, type of birth, dams age and sex of the calve influence the birth weight of purebred calves. Moreover, MacNeil *et al.* (1998) had reported that 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.

2.2.4 Dam's pelvic area

According to Scott (n.d), dystocia in cattle tended to be associated with smaller PA of heifers at 12 months of age to calf birth weight. Birth weight, the size of the PA of the dam, and the interrelationship between these two factors are determinants of dystocia (Merck Veterinary Manual, 2008: Online). According to Briedenhann (2010), there are two important factors to consider for calving ease. The first is the size of the pelvic opening (the bigger the better), and the second is the anatomy of the pelvis (abnormalities in the pelvis can cause dystocia).

2.2.5 Gestation length

The majority of fetus growth occurs in the final 60 days; however, setting up an effective nutrient transfer from the ewe to the fetus occurs with udder and placental development in the first trimester of pregnancy (Ferguson *et al.*, 2017). 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).

2.2.6 Body condition scoring of heifers

Body condition scoring (BCS) is an effective hands-on management tool that is used to evaluate the nutritional status of beef cattle. In order to manage a beef herd in the most cost-efficient way, producers must, at all times, be aware of the body condition of their herd. It has been indicated that through research the body condition of beef cows is related to many critical aspects of production, such as days to oestrus, conception rate, milk production and calving interval (Canadian Cattlemen's Association & National Farm Animal Care Council, 2013).

BCS is most applicable to mature cattle and may be of very little use for cattle under one year of age. By assessing the degree of muscle and fat cover at specific places on the mature animal's body, specifically over the spinous and transverse processes of the short ribs and in fatter cattle, the tail head and ribs, a BCS between one and five can be determined (CCA & NFACC, 2013). Body condition is a very important factor when considering ease of calving. The five condition scores as presented by Thompson & Meyer (1994) are as follows:

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

Condition score 2 (thin): Spinous processes are sharp and prominent. Loin eye muscle has little fat cover but is not 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).

2.2.7 Positions and presentations of the calf in the uterus

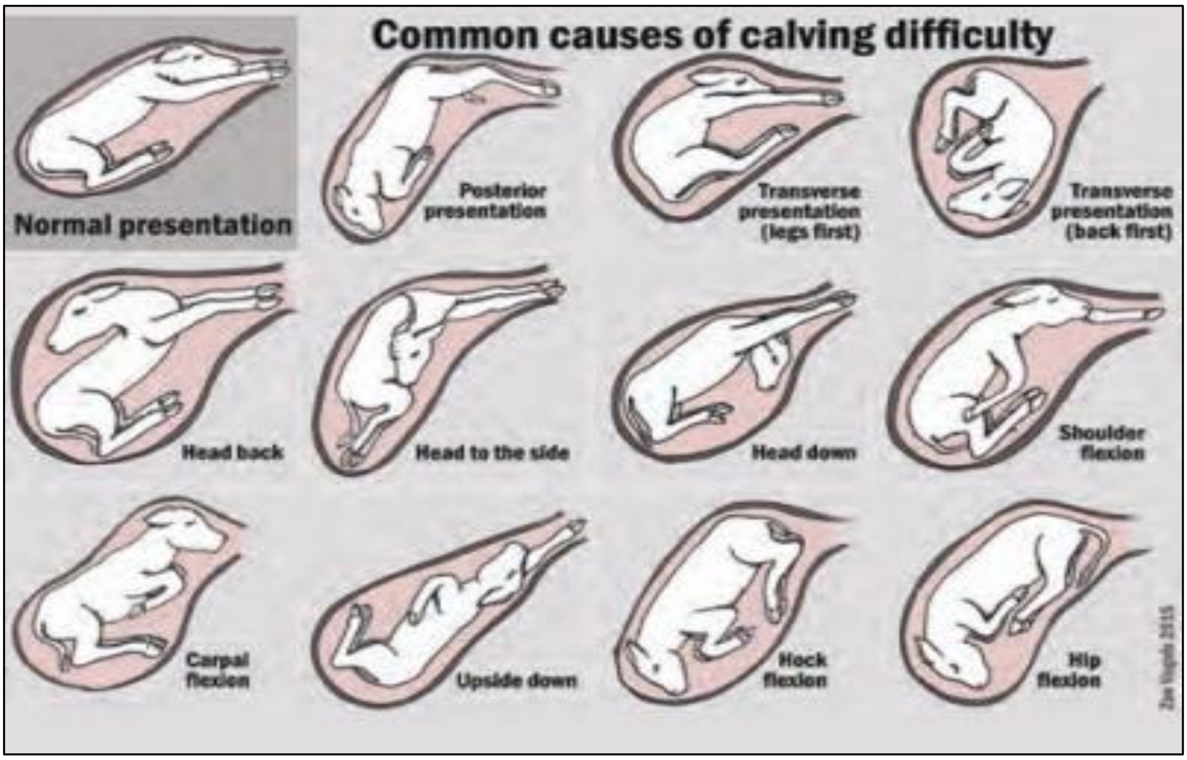

Figure 2. 2: A set of figures showing the different possible abnormal presentations of calves in a cow (Martin, 2008)

Abnormal presentations cause difficulties in calving. The positioning of calves in a normal presentation will entail that the feet are presented first within an hour just after the onset of labour, and the head follows on top of the knees (Anderson, 1992; Wilson & Rossi, 2006). There is usually 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 elapse before giving assistance. A 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; Wilson & Rossi, 2006).

2.3 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 (Johnston *et al.*, 2009). Therefore, the sire for each female should be well chosen. This will help eliminate mating large-framed sires to small-framed heifer's. Sires that produce low birth weight offspring must be mated with small heifers to reduce possible dystocia (Anderson, 1992; 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 fetuses. 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; Wilson & Rossi, 2006).

2.4 Fertility

A high level of fertility or reproductive performance is fundamental to an efficient beef cattle enterprise. Fertility is commonly measured in terms of calf crop percentage, and no single factor in commercial cow calf operation has a greater bearing on production in the herd (Olori *et al.*, 2002). Improving genomic technology have now made it possible to further enhance the predictability of our current selections with the incorporation of genomic values into our genetic evaluations thereby improving the accuracy of the EPDs, particularly in younger animals. Fertility, weaning weight and adaptation have been recognized as the most important traits for these systems (Laske *et al*., 2009).

However, this does not replace the importance of collecting actual phenotypic data. Female fertility is a complex trait that can be divided into at least two components: interval traits and success traits (Andersen-Ranberg *et al*., 2005). One of the most widely used interval traits is the interval from calving to first insemination, which describes the ability of a cow to show estrus after calving. Andersen-Ranberg *et al*. (2005) further reported that success traits, such as non-return rates, are related to the capability of a heifer or a cow to conceive when inseminated.

Selection for increased milk yield is, therefore, expected to result in genetic decline in a female fertility, implying that selection for fertility is necessary to genetically stabilize or improve female fertility (Andersen-Ranberg *et al.*, 2005). One can also argue that fertility is economically important, as Boichard (1990) has shown that herds with the same production level, but with 45% and 60% average conception rates respectively, differed in overall income by 10%. Given that fertility has a substantial economic value, as assumed in the Nordic countries, for example, selection based on fertility information will increase the accuracy of selection on the aggregate economic genotype. In a study by Scholtz *et al*. (1991), it was found that Nguni heifers needed a target weight of 215 kg at the onset of the breeding period, in order to conceive.

The heifer progeny of the heifers that calved early did not reach this target weight at 13-15 months of age. Thus, a system of early breeding could not be maintained in the study. According to Kroker *et al*. (2000), heifers, particularly those calving at two years of age took considerably longer after their first calving to return to oestrus. In many cases, heifers may become pregnant late or fail to conceive altogether.

2.5 Feeding

During pregnancy, high feed levels had no significant impact on birth weight or dystocia. Reduced feed levels, however, can actually cause weight loss, decreased milk production, increased incidence of scours and, most importantly, decreased pregnancy/conception rate (Goff, 2006). 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 PA

(Anderson, 1992; 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. Basically, fat animals will have high incidences of dystocia, similarly to underdeveloped/undernourished animals (Wilson & Rossi, 2006).

2.6 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 PH. Green *et al.* (1986) found a 0.61 genetic correlation between male and female PA. The heritability of PA is between (0.36 to 0.68), while the heritability of PH is greater than the heritability of the pelvic width. PA is more heritable than height or width (Boyles, 2000; Kinne, 2002). Some research has estimated the heritability of PA to range from 36% to 92 % with an average of 61%. These values indicate that PA 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 an 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 PA. According to Rushen *et al.* (2008), cow weight was the largest source of variation associated with PA, but breed adjusted for cow weight had a significant (P <0.01) effect on PA. Smith (2005) alleges that pelvic measurements can be successfully used to identify abnormally small or abnormally shaped pelvises.

2.7 Factors that influence dystocia can be grouped into two categories:

1. The figure below depicts the factors that affect the size and shape of the calf.

2. Factors affecting the ability of the dam to give birth are grouped in the figure below (Anderson, 1992).

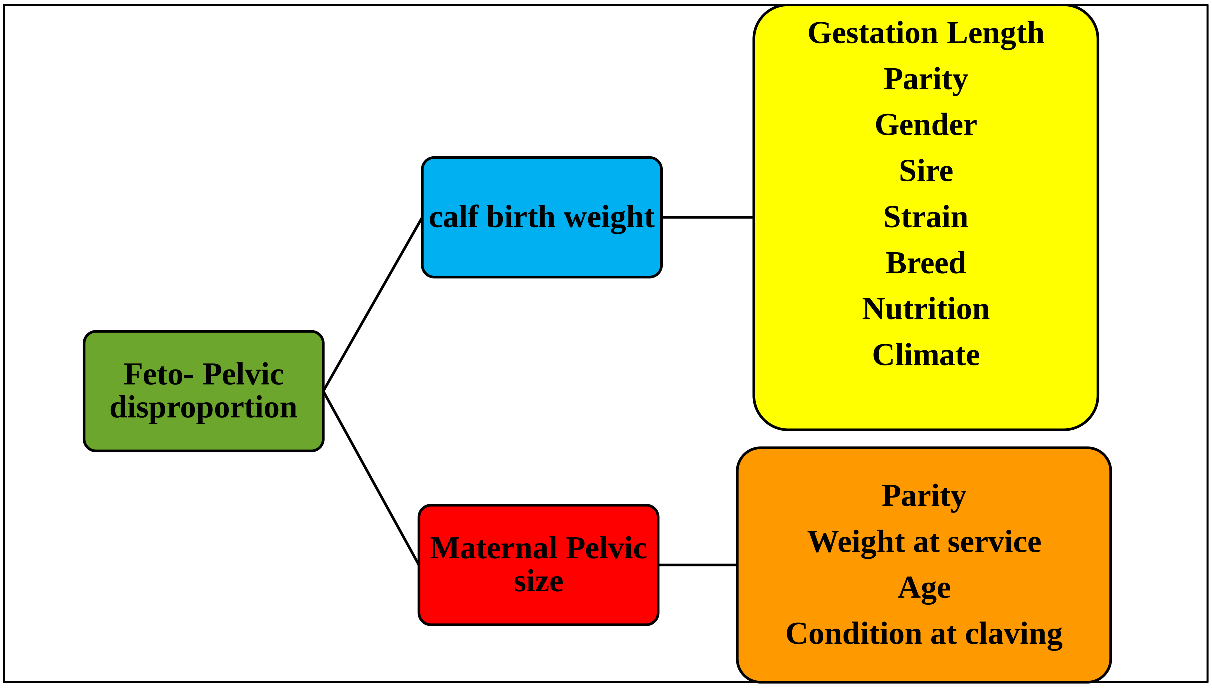

Figure 2. 3: An illustration of intermediate and ultimate cause of dystocia due to feto-pelvic disproportion (FPD) (Adapted from Mee, 2008)

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 *et al.* (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 contributing factor in neonatal lamb deaths due to pathophysiological handicaps imposed on the new born by asphyxic birth injury to the central nervous system. To buttress this point, Briedenhann (2010) noted that a disproportionally large calf size at birth in relation to the mother's pelvic area is one of the biggest causes of dystocia. Furthermore, 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, although Cloete *et al.* (1998) found this condition absent in Dormers, stating the significance (P <0.01) between breeds.

The interaction between the shape and size of the lamb and ability of the dam to give birth determines the incidence of dystocia (Anderson, 1992). It was 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 (Mee, 2008). 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 purebred and crossbred calves were analysed to determine the focus that should be given to dystocia and calve survival rates in selection programmes to determine sire breeds (Dhakal *et al*., 2013; Heins *et al*., 2010).

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 calve mortality by 8.6% in purebred and 4.8% in crossbred calves. Single born calves were heavier at birth and had fewer deaths than multiple born calves. Single born calves also had more dystocia than multiple born calves (Dhakal *et al*., 2013; Heins *et al*., 2010). Both dystocia and calve mortality were quadratically related (P <0.01) to birth weight (Dhakal *et al*., 2013).

Mellor & Diesch (2006) 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 breeds. 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 (Rushen *et al*., 2008).

Low life rearing efficiency, high levels of dystocia and parental mortality have been associated with small dimensions of the pelvic inlet and mature ewes (Van Rooyen *et al.*, 2012). Measuring PA would not be a cure-all against lambing problems; however, PA measurement is another useful tool in a comprehensive replacement ewe selection programme to reduce dystocia and perinatal instability in lambs and ewes (Troxel, 2008).

2.8 Alternative measures/strategies to prevent dystocia

According to Abdela & Ahmed (2016), dystocia causes a huge loss in dairy cattle herds and cannot be predicted but can be reduced by superior management of one's herd. Preventative management strategies include ensuring that bulls used for yearling mating are of the same breed, have low birth weight, estimated breeding values (EBVs) of sires are known not to result in larger mature sizes (Abdela & Ahmed, 2016). Replacement heifers should be well developed and fed adequately to reach 65% of their mature weight at breeding. Furthermore, since genetic selection could improve calving performance, it is important to include calving traits, such as dystocia, in genetic evaluations (Abdela & Ahmed, 2016). In order to prevent dystocia, there are five critical time periods (Mee, 2004) when action can be taken:

2.8.1 Choices at the heifer's birth

Primiparous cattle that had a heavy birth weight (as a calf) experience more severe dystocia as a two-year-old due to their initial heavier birth weights, which was probably genetically caused (Colburn *et al*., 1997).

2.8.2 Preservice period

Sire EPDs for low birth weights should be consulted in order to develop calves with smaller bone sizes and birth weights, especially if the animals to be bred are primiparous cattle (Colburn *et al*., 1997). Selecting for greater PH, PW, or PA can also help to reduce dystocia (Green, *et al*., 1988; Murray, *et al*., 1999). The use of internal pelvimetry measurements to remove heifers with small PA has also been advocated. However, pelvimetry performed at breeding or early stages of gestation is not capable of reliably predicting dystocia (Van Donkersgoed, 1992; Basarab *et al*., 1993; Van Donkersgoed *et al*., 1993).

2.8.3 During pregnancy

Using sexed semen or determining the fetal gender via ultrasound at 55 to 65 days of conception can help to anticipate increased dystocia risks due to male fetuses (Mee, 2004). Detection of twin fetuses will also compel farm personnel to pay closer attention to the dam at calving (Hiew, 2017).

2.8.4 Pre-calving

Reducing environmental stress at the time of calving is beneficial, especially for primiparous cattle and can be done by adapting them earlier to the maternity unit, calving them separate from multiparous cattle, keeping them loose and not tethered at calving, and avoiding disturbances from farm tasks (Mee *et al*., 2011).

2.8.5 During calving

Proper supervision at stage II of parturition with timely intervention can help prevent dystocia caused by prolonged calving and secondary uterine inertia (Mee, 2004) as insufficient monitoring might prolong the calving process and increase the risk of perinatal mortality (Gundelach *et al*., 2009). The choice to perform elective surgical interventions, such as Caesarean section or episiotomy, should be considered if it will prevent unnecessary trauma that may endanger the dam or fetus (Norman & Youngquist, 2007).

2.9 Pelvimetry

Pelvimetry is the measurement of the capacity and diameter of the pelvis, either internally or externally or both, with hands or with a pelvimeter (Blood *et al*., 2007). In cattle, internal pelvimetry has been used to determine PA and its association with calving difficulty (Deutscher 1991; Van Donkersgoed *et al*., 1993; Coopman, *et al*., 2003). Hiew & Constable (2015) reported that there is a rapid increase in PA just prior to calving due to the dilation caused by hormonal changes such as oestrogen and relaxin (Bagna *et al*., 1991). Therefore, the clinical utility of using intra-pelvic dimension to predict dystocia is controversial as some studies deem it as a useful predictor (Deutscher *et al*., 1999; Johanson & Berger, 2003) while others find that it is not (Basarab *et al.,* 1993; Van Donkersgoed *et al.*, 1993).

2.9.1 Pelvimetry measurements

Pelvimetry measurements are comprised of both the external and internal pelvic dimensions. External pelvimetry is done to correlate internal pelvic dimensions with measurements taken outside of the animal, like the distance between: the two tuber ischii (pin width), the two tuber coxae (hip or hook width), the anterior surface of the ilial wing and the posterior surface of the ischium (rump length), ilial wing to hip joint, and iliac crest to ischial tuberosity (Le Gal *et al*., 2010; Johanson & Berger; 2003, Coopman *et al*. 2003).

2.9.2 Heritability of intra-pelvic dimensions

Pelvic area has moderate to high heritability, ranging from (0.36 to 0.61), which suggests that it responds to selection (Hiew & Constable, 2015). Both PH and PW have a moderate to high heritability estimates with PW having higher values due to its more easily obtained measurements which leads to a higher repeatability (Van Rooyen *et al*., 2012; Hiew & Constable, 2015; Green *et al*., 1988). A useful correlation to examine would be the association between PA of bulls and the EPDs for daughters calving ease which might give an indication to determine if PA measurements would be a good selection criterion for bulls (Van Donkersgoed, 1992; Hiew & Constable, 2015).

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CHAPTER THREE

GENERAL MATERIALS AND METHODS

3.1 Materials and methods

3.1.1 Animals

One hundred and eighty-six (186) first-calf Sussex heifers approximately 24 months old, weighing approximately 350 kg were used for the purpose of this study. All heifers used for the study were in good body condition with average BCS of three, weighing more than 65% of the mature female body weight of the Sussex breed. Six two-year-old bulls, weighing approximately 800 kg were used for mating the 135 heifers during the first trial and with a bull ratio of (1:35; 1:35; 1:35 and 1:30). The second trial consisted of 51 heifers with a bull ratio of 1:30 and 1:21. All the bulls were tested for fertility by a private veterinarian before the mating season. They were managed extensively on the veld during the time of the trial, receiving production and salt licks as feed supplements. In order to exclude the camp effect, the heifers were rotated every two weeks among the eight camps that were made available on the farm for grazing purposes for the duration of the study (from September 2017-June 2019, figure 3.1).

During poor grazing seasons, a production lick [Molatek protein lick (40)] was used as a supplement at an intake of 1000 - 1500 g/heifer/day. Molatek Protein Lick (40) is a high-quality protein supplement, rumen degradable protein (RDP) for sheep and cattle grazing on winter pastures, and it is especially suitable for the sweeter grass veld regions (Bareki, 2010). It stimulates the intake of dry matter as well as digestion to restrict weight loss during the winter season (Bareki, 2010). This protein lick supplies all the necessary minerals and trace minerals to supplement pasture deficiencies. Table 3.1 indicates the nutrient composition and nutrient levels in each bag of the lick. Whereas table 3.2 shows the ingredients (per kilogram) in the compounded protein lick.

Table 3.1: Lick Composition

Nutrient composition	Nutrient levels (g/kg)
Protein	260g/kg
Urea	59,71g/kg
Calcium	20,0g/kg
Phosphate	6,6g/kg

Table 3.2: Protein lick ingredients

Ingredients	Levels (kg)
Molatek protein lick	100kg
Molasses meal/grain/chop	80kg
Total	**180kg**

3.2 Environment (Research area)

This study was conducted at Huntersvlei also known as Rhys Evans Group farm (RE) in the Free State. This farm is located in Viljoenskroon, Fezile Dabi municipality. Normally, Huntersvlei receives about 650mm of rain per year, with most rainfall occurring during mid-summer. It receives the lowest rainfall in June and the highest rainfall of approximately 75mm in January. The monthly distribution of the average daily minimum and maximum temperatures ranges from 12^{o}C-35^{o}C in summer, 8^{o}C-15^{o}C and evening time approximately -4-7^{o}C (Moeletsi, 2010).

The farm lands have varying soil types, including deep sandy soils, with four to seven percent of clay content and sandy-loam soils, with eight to twelve percent clay. The most dominant varieties of grasses in the area are *Themeda triandra* (Red grass) and *Digitaria eriantha* (Common finger grass). *Hyparrhenia hirta* (Common thatching grass) and *Eragrostis terff* (Teff grass) are planted to improve fodder flow during slump/dry seasons.

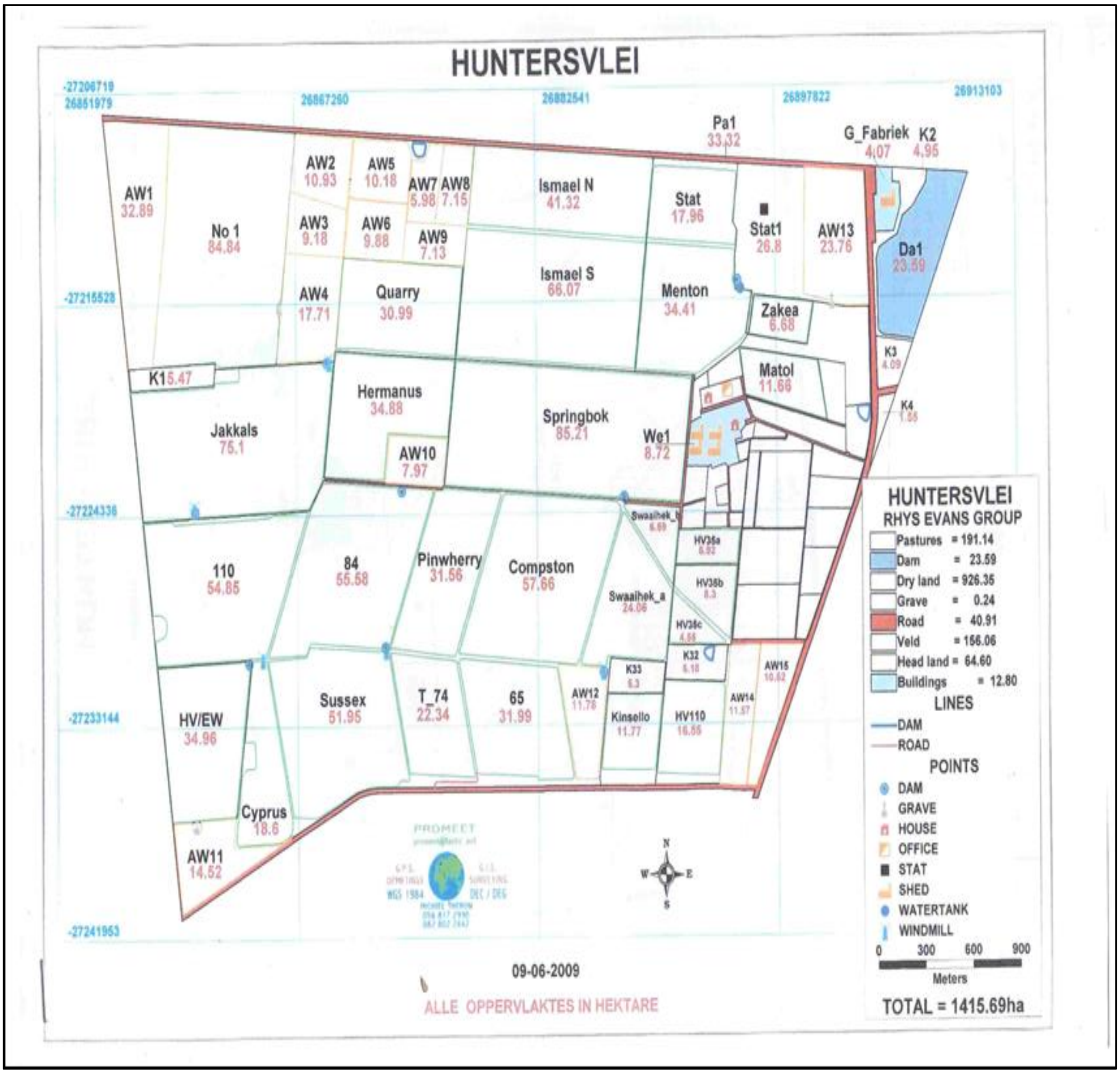

Figure 3. 1: Farm map (Huntersvlei farm on 15 April 2019)

3.3 Instrument

The Rice Pelvimeter is a measuring device for taking pelvic measurements. The instrument consists of two cast aluminium arms and a stainless-steel scale graduated in centimetres. The measurements (vertical and horizontal) were read on the inside of the measuring arms (see figure 3.2 below). Two measurements were made via the rectum.

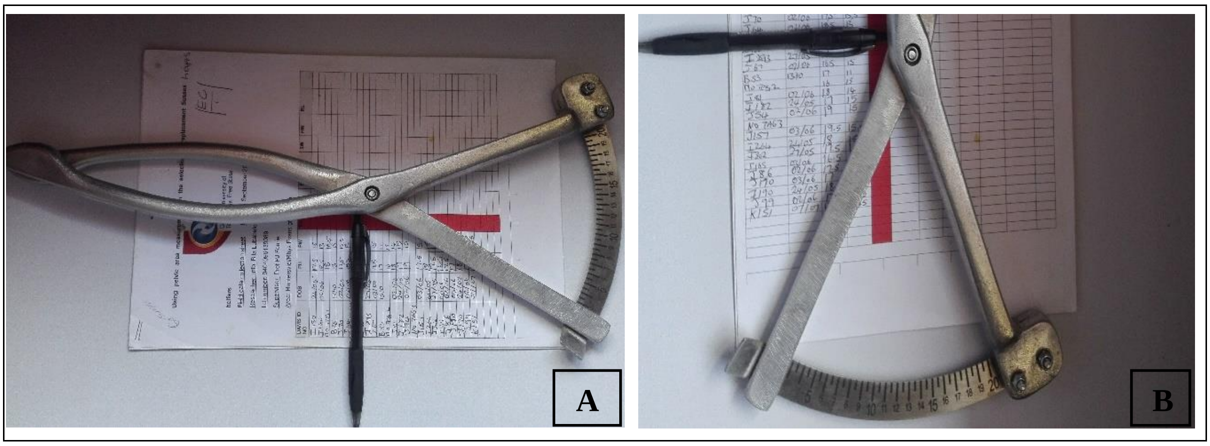

Figure 3. 2: [A & B] Pelvic meter used to measure pelvic dimensions in heifers (Picture taken on 15 April 2019)

3.4 Measurements

3.4.1 Pelvic area measurements

Figure 3.3 shows the measurements taken for the pelvis. Pelvic height was taken between the sacrum (spinal column) and the dorsal pubic tubercle on the floor of the pelvis. Pelvic width was measured at the widest point between the left and right ilium shafts (sides) of the pelvis (Van Donkersgoed, *et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Zyl, 2008; Van Rooyen *et al*., 2012;).

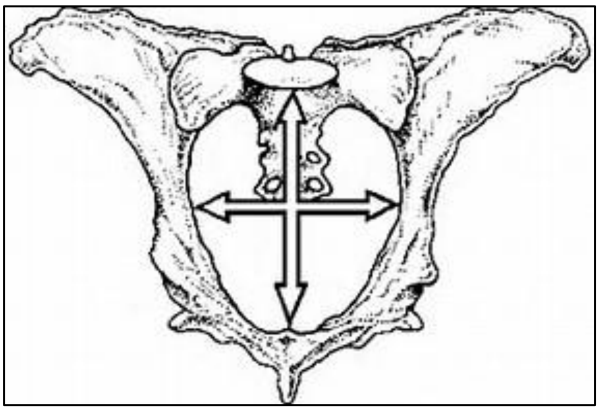

Figure 3. 3: Pelvic measurement area (Anderson & Bullock, 1994)

The general procedure in taking pelvic measurements is to restrain the animal in a chute using a light squeeze. A comfortable, normal standing position is best for this procedure. Faeces were removed from the rectum and the instrument was carefully placed into the rectum according to the procedure of Deutscher *et al*. (1999) and Van Zyl (2008). After introducing the instrument in the animal, the instrument was gradually opened by guiding it with handle. The instrument was then twisted from left to right to feel the ossified joint on the pubic symphysis as a reference point, for purposes of measuring the height between the dorsa pubic tubercle on the floor of the pelvis and the sacrum (spinal column) at the top (figure 3.3).

The instrument was then turned 90º sideways to measure the width of the pelvis at the widest points between the right and left shafts of the ilium bones (figure 3.3). This is the horizontal diameter of the pelvis (Van Donkersgoed, *et al*., 1990; Walker *et al*., 1992; Kilgour & Haughey, 1993; Patterson & Herring, 1997; Cloete *et al*., 1998; Van Zyl, 2008; Van Rooyen *et al*., 2012). 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 used on each 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 heifers were measured once before breeding, using a method adapted from (Walker *et al*., 1992; Kilgour & Haughey, 1993; Patterson & Herring, 1997 and Van Rooyen *et al*., 2012). The following formula was used to calculate Pelvic area:

$PA \quad = \pi(\frac{PH}{2} \times \frac{PW}{2})$ (Morrison *et al*., 1986; Van Rooyen *et al.*, 2012).

3.4.2 Pelvic area and certain body measurements

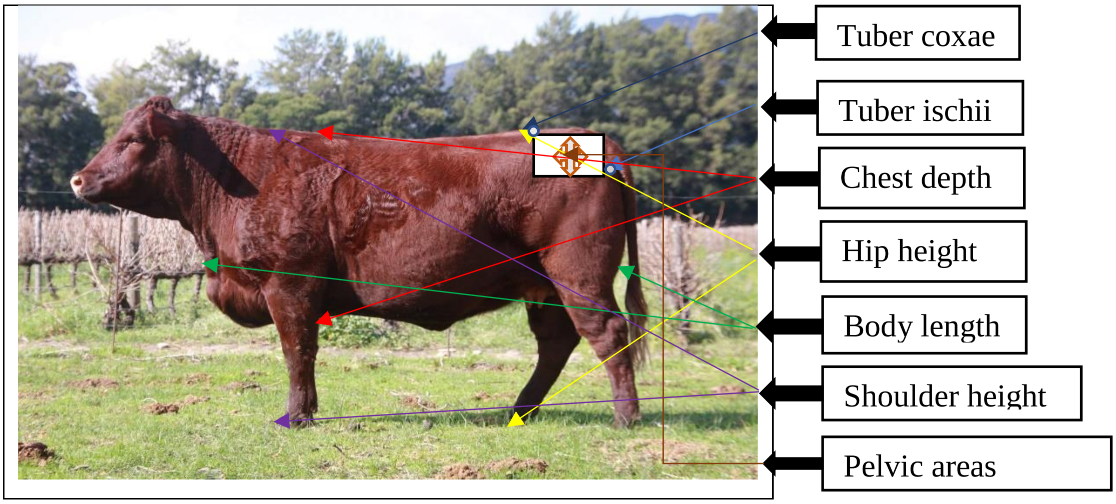

Figure 3. 4: Illustration depicting points of measurements (Picture taken on 20 April 2019)

During the parturition process, the calving ease score codes were used to score each heifer that calved. The scores ranged from one, (no assistance; cow can calf on the veld without any assistance) to six (abnormal foetus position - calf came backwards or in an abnormal position) (Table 3.3).

Table 3.3: Calving ease score, codes and description

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

Source: Fourie *et al*. (2002)

3.5 Body condition scoring of heifers

Body condition scoring is most applicable to mature cattle and may be of very little use for cattle under one year of age. By assessing the degree of muscle and fat cover at specific places on the mature animal's body, specifically over the spinous and transverse processes of the short ribs and in fatter cattle, the tail head and ribs, a BCS between one and five can be determined (CCA & NFACC, 2013). Body condition is a very important factor when considering ease of calving. 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).

3.5 Data analysis

The collected data was captured in Microsoft Office Excel, and cleaned before the analysis. Descriptive statistics such as mean, standard deviation, coefficient of variation and correlation coefficient for each one of the traits were conducted to determine the relationship between all parameters. Analysis of variance (ANOVA) was done using SPSS to determine the statistical significance of the variables. A stepwise regression analysis was carried out to determine the individual influence of body measurements on PA. Statistical analysis made use of pictorials (e.g. histograms, graphs, etc.) to present some results. In order to identify and group the patterns of genetic variation, Principle Component Analysis (PCA) was conducted. Statistical significance was set at (P <0.05).

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CHAPTER FOUR

THE RELATIONSHIP BETWEEN PELVIC AREA, PELVIC DIMENSIONS AND DYSTOCIA

4.1 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 *et al.*, 2011). Low lifetime nurturing and the perinatal mortality period (shortly before, during or within seven days after birth) has been associated with the small pelvic area of dams (Mee *et al*., 2011; Van Rooyen *et al*., 2012). According to Troxel (2013), the primary cause of dystocia is a disproportionately large calf size or BW compared to the PA (birth canal) of the cow or heifer. It would thus, make sense to include PA as a criterion for selecting breeding dams (or rather to eliminate dams with small PA). However, measuring it *in vivo* poses some challenges (internal measurements) due to the reduced size of sheep when compared to cattle (Van Rooyen *et al*., 2012).

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 (Mee *et al.*, 2011). The study on sheep conducted by Van Rooyen *et al*. (2012) indicated no significant correlations between pelvic measurements and other body measurements considered in the study, indicating the need to directly measure the PA.

According to De Maturana *et al*. (2007), animals that experienced extreme dystocia, produced less milk than animals that experienced no dystocia. Small pelvic dimensions in dams have proven to be associated with high levels of dystocia and poor lifetime nurturing performance (Kilgour & Haughey, 1993; De Maturana *et al*., 2010). The aim of this study was to investigate the correlations between pelvic measurements (height, width and area) and calving ease in Sussex heifers as well as to investigate whether the selection according to breed standards resulted in indirect selection for different pelvic areas in heifers.

4.1.1 Materials and methods

The basic experimental procedure that was followed is laid out in chapter 3. Only pelvic area measurement procedures in 135 Sussex heifers, BW and gender of the calves were followed for this experimental chapter. No external body measurement in heifers was done.

4.2 Results and discussion

4.2.1 Pelvic dimensions

The mean and variance difference PH and PW were different (*P* <0.05) among heifers (Table 3). This result is in agreement with the report of Kolkman *et al*. (2009) in Belgium Blue cows, stating that there is a significant difference (*P* <0.05) in these three pelvic dimensions (PW, PH and PA). The result, however, disagrees with Van Rooyen *et al*. (2012), who revealed that the mean difference between PH and PW is very similar and PA recorded a small variance among yearling ewes. The difference in pelvic size is usually attributed to the difference in PH (Van Rooyen *et al*., 2012). Heritability of PH is greater than that of PW whereas pelvic area is more heritable than PW or PH (Boyles, 2000).

Table 4.1: Mean and standard deviation of pelvic area measurements in Sussex heifers

Pelvic Parameters (cm)	Mean ± SD
PH (cm)	16.61 ± 1.14
PW (cm)	13.16 ± 0.89
PA $(cm)^2$	171.95 ± 19.12

From Table 4.1, it is evident that PH (16.61 cm) is bigger than the PW (13.16 cm) in the first calving Sussex heifers of the same age group. The mean PA of the heifers in this study is 171.95 ± 19.12 cm^2. Green *et al*. (1986) reported a 61% generic correlation between male and female PA in cattle. Therefore, this shows that taking into consideration the pelvic areas of both sire's and dams when replacing heifers in the herd may have a great influence in reducing dystocia in the beef cattle industry.

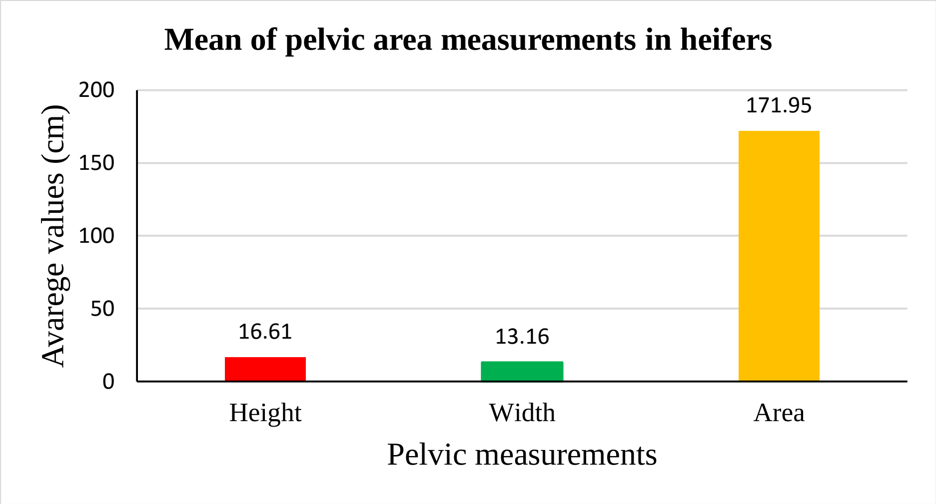

Figure 4. 1: Histogram showing the mean pelvic areas of Sussex heifers

The two figures 4.2 & 4.3 below portray the positive correlation between PW, PH and PA in this study. As it can be seen in the figures that there is a high correlation of 0.81 (*P* <0.01) between PH and PA, as well as 0.82 (*P* <0.01) between PW and PA.

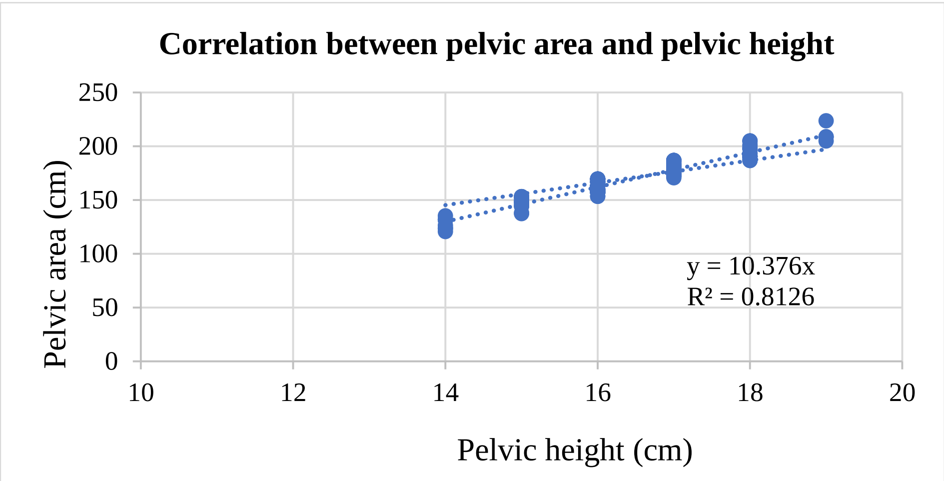

Figure 4. 2: Linear relationship between pelvic area and pelvic height (cm^2)

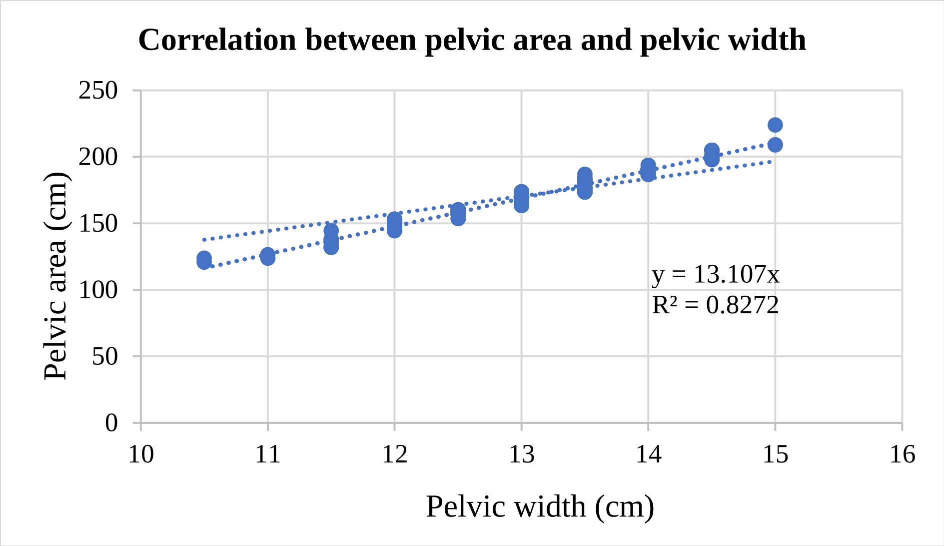

Figure 4. 3: Linear relationship between pelvic area and pelvic width (cm^2)

Pelvic height also showed a high positive correlation of 0.90 (*P* <0.01) (Figure 4.4) with PW. In general, all the pelvic area measurements recorded a positive correlation between each other in this study. Smith (2005) stated that the growth of PW and PH differ between frame sizes of beef heifers. The reason for the high positive correlation between PH and PA (0.81, *P* <0.01), as well as between PW and PA (0.82, *P* <0.01), is because, these two measurements have a direct influence on calculating PA.

It seems that in Sussex heifers, both PW and PH has a significant influence on the PA, as PH and PW increase cause a positive increase in PA of heifers, judged by the correlation coefficients (0.82 and 0.81, respectively). This is in contrast to what was reported by Van Rooyen *et al*. (2012) in their study, stating that in sheep, PW has a greater influence than PH on PA, judged by correlation coefficients as well (0.94 vs 0.84). Heritability of 50%-60% was found in sheep (Kinne, 2002) and 36%-92% in beef bulls (Deutscher, 1991), with PH estimates more heritable than PW estimates, and PA is more heritable than height or width (Anderson & Bullock, 1994; Patterson & Herring, 1997).

According to Hiew & Constable (2015) PA has a moderate to high heritability, ranging from 0.36 to 0.61 which suggests that it responds to selection. Both PH and PW have a moderate to high heritability estimates with PW having higher heritability values in most studies due to its more easily obtained measurements which leads to a higher repeatability (Hiew & Constable, 2015).

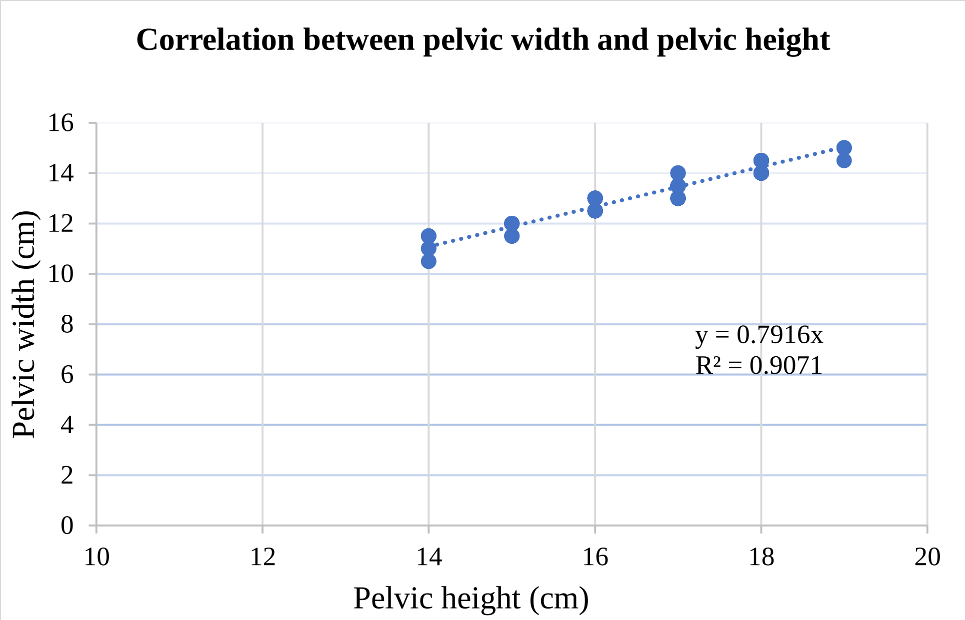

Figure 4. 4: Linear relationship between pelvic width and pelvic height

4.2.2 Pelvic areas and dystocia

From figure 4.5, it is evident that most of the calves born were males (53.3%), versus 46.7% females. The results revealed that the independent variables (sex of the calf) made a statistically significant (*P* <0.05) contribution to predicting calving ease. Johanson & Berger (2003) stated that an 11% decrease in odds of dystocia is associated with one square decimetre (cm^2) increase in PA. In addition, the odds of the dam being given a calving ease score above one was 6.22 times greater when the calf was male than female.

This is in agreement with what was reported by Johanson & Berger (2003), who stated that, apart from the inclusion of calf weight in the multiple regression model, sex of the calf still had a significant effect on the likelihood of dystocia, this indicates, therefore, that differences between calf sex other than birth weight influence dystocia. Johanson & Berger (2003) also reported that the odds of male calves needing assistance was 25% greater than when the calve was female. By nature, the morphology of male calves is bigger, and they have broader shoulders compared to female calves. This may possibly lead to heifers who give birth to males being much more prone to dystocia.

A large percentage of bull calves (40%) required assistance compared with female calves (33.0%) in a study by Lombard *et al.* (2007), extended mentioning that dystocial calves frequently have a depressed central nervous system, which reduces the stimulation for respiration. This depression also results in decreased physical activity and might prevent calves from standing or taking longer than normal to stand.

Van der Merwe and Schoeman (1995) including Johanson & Berger (2003), reported on the contributing factors to calving difficulty, including body weight at breeding, birth weight and sex of the calf, although birth weight did not play a significant role in predicting dystocia in their studies. However, it was one of the factors which contributed irrespective of the percentage each factor contributed. Birth weight is no longer a significant effect, as it was expected to be an important factor in the study, but its importance seems to diminish when the sex of the calve is included in the analysis.

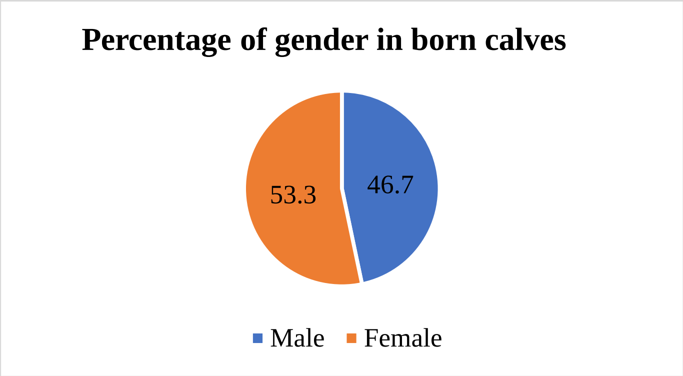

Figure 4. 5: Genders percentage of the born calves

There were varying reasons for the heifers that suffered from dystocia. According to figure 4.6, 83% of heifers calved on the veld without any assistance, whereas 4% of heifers struggled during parturition, either with stillbirth calves or calf mortality within 48 hours after-birth. These were as a result of difficult calving and not due to predators. Ten percent (10%) of heifers could not calf unassisted so the calf was removed from the heifer using alternative ways. Three percent (3%) of heifers were assisted by hard-pulling of the calves out of the birth canal due to difficult delivery.

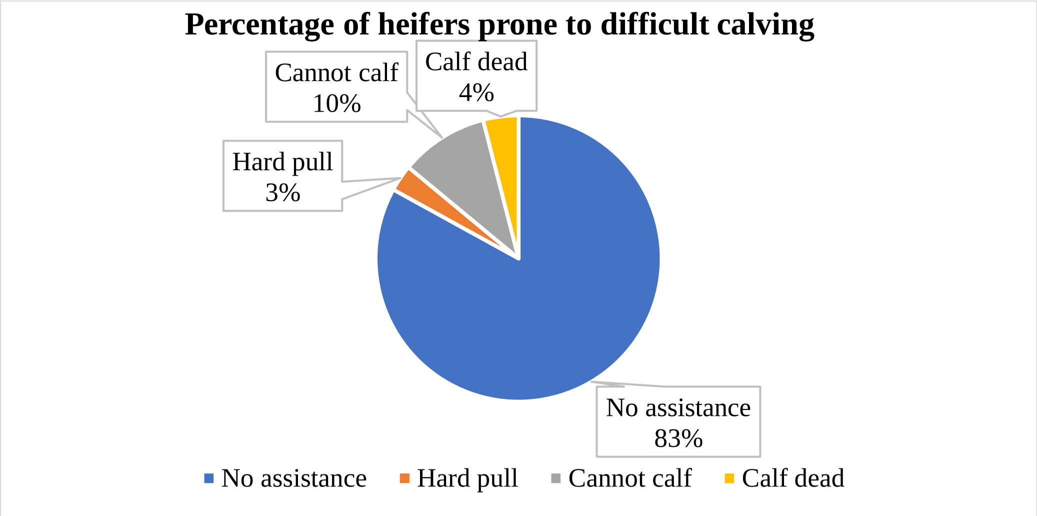

Figure 4. 6: A pie chart showing the varying rates of the factors that contributed to dystocia in the experimental heifers

In figure 4.6, it can be seen that most heifers (83%) managed to calve unassisted in the veld, whereas (17%) of the heifers had to be assisted for some reason. Such reasons include mal-presentation of foetus and high calf birth weight.

4.3 Principle Component Analysis (PCA)

The blue dots represent the different heifer sample (Figure 4.8), while the red lines represent different variables. The lines of variables that are closer to the wall of the circle indicate how well the variables were described by PCA. This means that the longer lines are the well-suited variables described by PCA. Correlation structures between variable loadings represent the correlation scale and the central data.

The number of factors retained in the model for the proper classification of the data (Table 4.2) was determined by the application of Kraiser & Rice's (1974) method. Out of twelve principal components (PCs), the first four exhibited eigen value greater than one (significant), while the rest of eight PCs exhibited less than one (non-significant) variation so they were not worth interpreting (Figure 4.8). Amongst the observed variables only four principal components accounted for most of the variabilities, they showed accumulative variability greater than 63.86% of the total variance. The first principal component accounted for 24.68%; the second principal component accounted for 17.32%, and the third principal component accounted for 12.10%, whilst the fourth principal component accounted for 9.76% of the total variance respectively (Table 4.2).

The principal component analysis (PCA) explained the genetic diversity of the evaluated accessions. PCA measures the contribution of each component to the total variance, while each factor loading specifies the amount of contribution of every trait with each principal component associated with that trait (Dube *et al*., 2018). Each trait was regarded as an important contributor to the variability in a component if its factor loading had a total value ≥0.40, irrespective of the plus or minus sign. This was also reported by other researchers (Dube *et al*., 2018). Morphological characterisation of animal breeds is an important step in animal improvement programmes as it permits breeders to identify and select superior blood lines for further animal advancement (Julia *et al*., 2016; Ngomuo *et al*., 2017; Dube *et al*, 2018). The genetic parameters such as genetic variances and heritability are very important in selection for superior parental blood lines in breeding programmes (Dube *et al.*, 2018).

Table 4.2: Principal components for twelve attributes/parameters

	PMPH	PMPW	PMPA	BMLW_18	BMLW_C	SEX	BW	CES	DBE	SI	SBE	ICP
Eigen value	**2,962**	**2,079**	**1,453**	**1,172**	0,959	0,759	0,679	0,659	0,504	0,460	0,314	0,001
Variability (%)	**24,687**	**17,322**	**12,104**	**9,769**	7,992	6,326	5,659	5,491	4,196	3,831	2,615	0,009
Cumulative %	24,687	42,009	54,113	63,882	71,874	78,200	83,858	89,349	93,546	97,376	99,991	100,000
Eigenvectors												
	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
PMPH	**0,455**	-0,074	-0,144	0,076	0,089	**-0,434**	-0,341	-0,124	0,207	0,393	0,129	**-0,468**
PMPW	**0,413**	-0,092	-0,317	-0,059	0,063	**0,473**	0,262	-0,202	-0,278	-0,269	-0,159	**-0,453**
PMPA	**0,527**	-0,107	-0,283	0,012	0,093	0,010	-0,052	-0,185	-0,043	0,083	-0,021	**0,759**
BMLW _18	0,308	-0,285	0,235	0,069	-0,007	-0,274	-0,025	**0,637**	**-0,470**	-0,240	0,056	-0,008
BMLW_C	0,233	-0,266	**0,417**	0,019	0,177	**0,549**	-0,094	0,208	**0,501**	0,037	0,253	0,003
SEX	-0,013	-0,164	0,001	**0,779**	-0,089	-0,033	**0,524**	0,014	0,073	0,264	-0,086	-0,002
BW	0,181	0,361	**0,441**	-0,098	-0,207	0,219	0,056	-0,130	**-0,460**	**0,543**	0,124	0,004
CES	0,201	0,337	-0,002	-0,395	0,268	-0,207	**0,590**	0,311	0,293	0,125	-0,172	-0,003

PMPH= Pelvic measurement pelvic height; PMPW= Pelvic measurement pelvic width; PMPA= Pelvic measurement pelvic area; BMLW-18= Body measurement live-weight 18months; BMLW-C= Body measurement live-weight at calving; BW= Birth weight; CES= Calving ease score; SI= Sire; ICP= Inter-calving period; Sex= Gender; DBE= Dams birth-weight estimated breeding values and SBE= Sires birth-weight estimated breeding values. Values in bold are significant with *P* <0.05.

The first PC was highly related to the dam's pelvic area measurements namely PH, PW and PA. These three generic attributes contributed significantly (*P* <0.05) in predicting dystocia, as they play a positive role in calculating the PA of heifers. This is in agreement with what was reported in the study of Zaborski *et al*. (2009), where the various factors affecting dystocia in cattle included mal-presentations, uterine torsion, calf BW, multiple calving, perinatal mortality, cow PA, cow body weight, body condition at calving, gestation length, cow age and parity, the year and season of calving, the place of calving, maintenance practices, disorders, nutrition, and the calf's sex.

In PC2, there were no phenotypic attributes that mainly contributed to the variability among accessions. The traits of significant importance in PC3 that affected calving ease were live weight of the dam at calving and calf's BW. In PC4, the traits of significant importance were sex of the calf (0.77), which played a negative significant role in predicting dystocia (Figure 4.8). These findings are the same as the one obtained among correlation traits which stated that dams who gave birth to male calves are more prone to dystocia, due to the morphology of the male calf.

This study revealed that the dam given a calving ease score above one was 6.22 times greater when the calf was male than when the calf was female. In other words, a dam who gave birth to a male calf was 6.22 times more likely to be given calving ease score above one than a dam who gave birth to a female calf. On the basis of this analysis, promising genotypes have been identified, and these are suggested to be used for genetic improvement through the selection of replacement heifers and selecting the right bull for mating with a certain group of heifers with lesser chances of dystocia, considering the EBVs. All these parameters are important for the description of the genotypes, as the quantitative traits are more economically important and are generally used for the improvement of herds (Dube *et al.,* 2018).

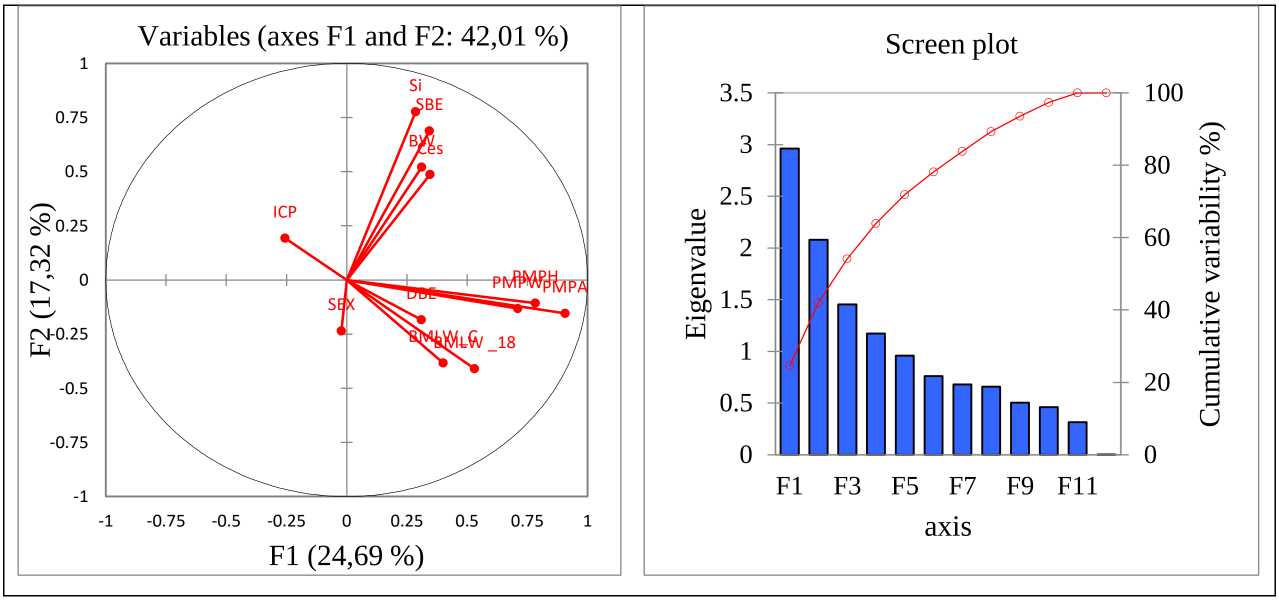

Figure 4. 7: Screen plot between eigen values and numbers of PCA

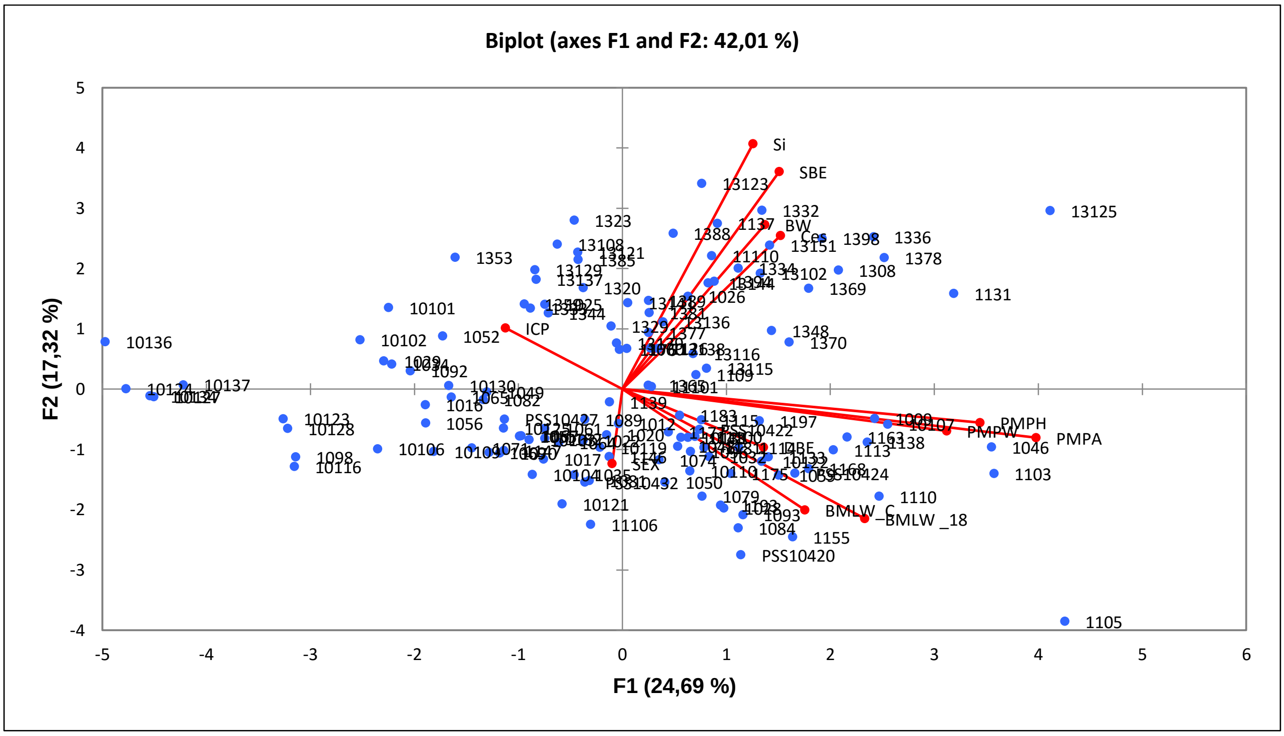

Figure 4. 8: Principal component biplot of all traits

4.4 Conclusion

The results of this study used two types of analysis; correlation matrix and PCA to indicate that PA measurements measured prior to mating have a moderate significance when sex and BW of the calves are included in the analysis. This was as a result of the fact that heifers were more prone to dystocia when they calved males. High birth weight of the male calves contributed a marginal percentage in predicting dystocia. Measuring PA prior to mating, and culling heifers with small PA may reduce dystocia in beef herds during parturition.

Overall it can be concluded that there is a high significant relationship between PA dimension in Sussex heifers, as they all have a direct influence on the PA. Pelvic area measurements must be measured directly before mating and shortly before or after parturition, as measurements can be influenced by rapid hormonal deposition during pregnancy. Pelvic area must be calculated accurately in order to eliminate heifers with small PA to reduce dystocia, since these parameters seem to be the most important factors that influence dystocia in many herds.

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CHAPTER FIVE

THE RELATIONSHIP BETWEEN PELVIC DIMENSIONS AND BODY MEASUREMENTS (PRE-BREEDING) IN PREDICTING DYSTOCIA IN TWO-YEAR-OLD HEIFERS

5.1 Introduction

Dystocia is related to an increase in the post-partum interval, 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 (Van Rooyen *et al*., 2012). In cattle, internal pelvimetry has been used to determine PA and its association with calving difficulty (Hiew & Constable, 2015). Both internal and external pelvimetry is done to correlate pelvic dimension with certain external body measurements such as the distance between the two tuber ischii (pin width), the two tuber coxae (hip or hook width), the anterior surface of the ilial wing and the posterior surface of the ischium (RL), ilial wing to hip joint, and iliac crest to ischial tuberosity (Coopman *et al*., 2003; Hiew & Constable, 2015). Internal pelvic dimension consists of the PH which is measured on the midline between the pubic symphysis and mid-sacrum, and PW which was measured at the widest point between the shafts of the ilia (Hiew & Constable, 2015).

Body size and 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 in livestock production. Therefore, constant checks on the relationships between body measurements and performance traits are vital in selection programs (Fourie *et al*., 2002). The aim of this study was to investigate and quantify the correlation between pelvic measurements (PH, PW and PA) and certain external body measurements (LW, CD, SW, HW, HH, BL, RL, RS and CM) in Sussex heifers.

5.1.1 Materials and methods

The basic experimental procedure followed is laid out in chapter 3. Both pelvic areas and external body measurements procedures in 51 Sussex heifers were followed for this experimental chapter.

5.1.2 Body measurements

The following body parameters were measured according to methods described by Fourie *et al*. (2002): live weight (LW); hip height (HH); chest depth (CD); shoulder width (SW); hindquarter width (HW), birth weight (BW), body length (BL), sex of the calf and rump length (RL). These parameters correlate with the PH, PW and PA. In addition, the heifers were assessed visually for body conformation (CM) and selection type (S), as described by the Sussex breed Standards of Excellence, on a scale of 1-5 were allocated to each animal. Conformation scores range from one (being very poor) to 5 (being very good). Rump slope (RS) scores ranged from 1 (being very flat) to 5 (being very droopy):

- Live weight (kg) was measured following a 12-hour fasting period;
- Shoulder height (cm) was measured vertically from the thoracic vertebrae to the ground (Fourie *et al*., 2002);
- Chest depth was measured from the spianus to the oxyfoid process of the sternum (Fourie *et al*., 2002);
- The hindquarter width (cm) was measured between the left thurl to the right thurl;
- Rump length (cm) was measured as the distance from the tuber coxae to the pin bone;
- Hip height (cm) was measured as the distance from the ground just in front of the hind hoofs over the hook (hip);
- Birth weight of the calve (kg);
- Sex of the calf (female coded two and male one);
- Body conformation; and
- Rump slope.

5.2 Results and discussion

5.2.1 Pelvic dimensions and calving ease score

Table 5.1 depicts the mean and standard deviations of the external body measurements: body length 149.24 ± 7.72 cm; chest depth 67.43 ± 4.25 cm; hip height 128 ± 5.57 cm; hindquarters width 52.92 ± 3.72 cm; rump length 47.47 ± 2.43 cm; shoulder height 124.55 ± 4.46 cm; calf birth weight 35.38 ± 5.53 kg and internal pelvic areas (PH 18.0 ± 0.74 cm and PW 15.88 ± 0.75 cm) that were measured during the trial in two-year-old Sussex heifers. The difference in pelvic size is usually attributed to the difference in PH (Anderson & Bullock, 1994 and Van Rooyen *et al*., 2012).

Table 5.1: Mean (±SD) of parameters measured during the trial in young heifers

Parameters	Mean± SD
Body length (cm)	149.24 ± 7.72
Chest depth (cm)	67.43 ± 4.25
Hip height (cm)	128 ± 5.57
Hindquarters width (cm)	52.92 ± 3.72
Rump length (cm)	47.47 ± 2.43
Shoulder height (cm)	124.55 ± 4.46
Calving ease score	1.49 ± 0.73
Live weight at 18months (kg)	437.31 ± 40.26
Live weight at calving (kg)	536.39 ± 50.03
Birth weight of the calves (kg)	35.38 ± 5.53
Pelvic area $(cm)^2$	224.70 ± 16.69
Pelvic Height (cm)	18.0 ± 0.74
Pelvic width (cm)	15.88 ± 0.75

Table 5.2: Non-parametric correlation between pelvic dimensions and calving ease score

	Spearman's rho	CES
Pelvic area	Correlation coefficient	**-0.26**
	Sig. (1-tailed)	**0.03**
	N	51
Pelvic height	Correlation coefficient	**-0.40**
	Sig. (1-tailed)	**0.00**
	N	51
Pelvic width	Correlation coefficient	-0.06
	Sig. (1-tailed)	0.31
	N	51

Values in bold are significant with P <0.05.

One of the aims of this chapter was to determine if there is a negative correlation between CES and pelvic dimensions. Due to the fact that CES is an ordinal variable and not a continuous variable, the non-parametric Spearman's rho was conducted in order to determine the correlations between calving ease score and pelvic measurements. The results of the Spearman's correlation test shown in Table 5.2.

The results of a one-tailed Spearman correlation test indicate that there is a significant negative correlation between CES and PA, r = - 0.266, P = 0.03 at an alpha level of 0.05. The strength of the association, for absolute values of r, 0-0.19 is regarded as very weak, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as very strong correlation (The BMJ, 2019). Therefore, the strength of the negative correlation is weak. These results show that as the pelvic area increases, the lower the chances of heifers to experience dystocia. The value of R^2 is 0.071, indicating that 7.1% of the variation in CES can be explained by the PA. This finding is in agreement with the study of Briendenhann (2010), who revealed that a disproportionally large calf size at birth in relation to the dams PA is one of the biggest causes of dystocia.

The results of a one-tailed Spearman correlation test indicate that there is a significant negative correlation between CES and pelvic height (PH) r = - 0.407, P = 0.003 at an alpha level of 0.05. Therefore, there is a moderate negative correlation between CES and PH (The BMJ, 2019). These results are revealing that as the PH increases there is a lesser chance for a heifer to experience dystocia. The value of R^2 is 0.1656, which means that 16.56% of the variation in

CES can be explained by the PH variable. The results of a one-tailed Spearman correlation test indicate that there is no significant negative correlation between CES and PW r = - 0.069, *P* = 0.316 at an alpha level of 0.05. This is in contrast with Briedenhann's (2010) study, where it was reported that PW is more important in *Bos Taurus* cattle, while PH is a more important factor in *Bos indicus* cattle to predict dystocia.

Table 5.3: Non-parametric correlation between live weight, birth weight and calf gender

	Spearman's rho	CES
Live weight 18m	Correlation coefficient	0.12
	Sig. (1-tailed)	0.19
	N	51
Live weight calving	Correlation coefficient	-0.03
	Sig. (1-tailed)	0.39
	N	51
Calf gender	Correlation coefficient	**-0.35**
	Sig. (1-tailed)	**0.00**
	N	51
Calf birth weight	Correlation coefficient	**0.31**
	Sig. (1-tailed)	**0.01**
	N	51

Values in bold are significant with *P* <0.05.

The study further explored to determine if there is a significant relationship between CES and the following variables: live weight 18months (LW18m), live weight at calving (LWC), calf gender, and calf birth weight (BW). Due to the fact that CES is an ordinal variable and not a continuous variable the non-parametric Spearman's rho was conducted in order to determine these correlations between these variables. The results of the Spearman's correlation test shown in Table 5.3.

Pelvic size, calf birth weight and their ratio are the most important factors for predicting dystocia in Sussex heifers. Calf birthweight is influenced by genetics and breed of the sire and dam, as well as the nutritional factors and gestation length of primiparous dams (Van Nieuwenhuizen *et al.*, 2017). Mellor & Diesch (2006) reported that larger heifers have larger pelvic openings and have higher birth weights. The results of a one-tailed Spearman correlation test indicate that there is no significant negative correlation between CES and LW18m, r = 0.124, *P* = 0.193 at an alpha level of 0.05. Furthermore, the results of a one-tailed Spearman correlation test indicate that there is no significant negative correlation between CES and LWC, r = -0.039, *P* = 0.393 at an alpha level of 0.05.

The results of a one-tailed Spearman correlation test indicate that there is a significant negative correlation between CES and calf gender, bearing in mind that 1=male and 2=female, r = -0.355, P = 0.005 at an alpha level of 0.05. Therefore, there is a weak negative correlation between CES and PH (The BMJ, 2019). Moreover, the chances of a heifer to experience dystocia are more when a male calve is born compare to female calves. The R^2 is 0.126, indicating that 12.6% of the variation in CES can be explained by the gender of the calf. These findings are in agreement with Johanson & Berger (2003), who stated that the odds of male calve needing assistance was 25% greater than when the calf was female.

The results of a one-tailed Spearman correlation test indicate that there is a significant positive correlation between CES and BW, r = 0.312, P = 0.013 at an alpha level of 0.05. Therefore, there is a weak positive correlation between CES and BW (The BMJ, 2019). The higher the birth weight of the calf, the higher the probability of a heifers to be prone to dystocia. The value of R^2 is 0.097, which means that 9.7% of the variation in CES can be explained by the BW variable. These findings are in contrast with the report of Johanson & Berger (2003), who revealed that the significance of calf birth weight diminish when the gender of the calf is included in the analysis. Deutscher (1991) indicated that the major cause of dystocia is a disproportion between the offspring's birth weight and the dam's pelvic area.

In a study of Van Der Merwe (2017), it has been revealed that a 270 kg Brangus heifers should have an average PA of of 132 cm^2 to deliver a 28.5 kg calf. Smaller dimensions should be considered for culling, but the area can be smaller in small framed cattle. The ratio between PA and BW resulted in a ratio of 4.74 kg calf/cm^2. The current study revealed that Sussex heifers have a bigger ratio compared to Brangus breed, as the mean PA recorded was 224.70 cm^2 and the birth weight of calves detailed 35.35 kg, the below equation was used to calculate the ratio between PA and BW that resulted in 6.35kg calf/cm^2 pelvic area.

$$\text{Ratio} = \frac{\text{PA}}{\text{BW}}$$

Table 5.4: Correlation matrix between PH, PA and phenotypic body measurements

	Pearson Correlation	**Pelvic area**	**Pelvic height**
Body length	r	0.35	0.42
	p	0.01	0.00
Chest depth	r	**0.59**	**0.46**
	p	0.00	0.00
Hip height	r	0.52	0.40
	p	0.00	0.00
Hindquarters width	r	0.46	0.42
	p	0.00	0.00
Rump length	r	0.39	0.22
	p	0.00	0.11
Shoulder height	r	0.48	0.39
	p	0.00	0.00

Values in bold are significant with $P < 0.05$.

Due to the fact that there was a positive correlation between PH, PA and CES, regression analysis was conducted to determine which body measurements explain the largest amount of variation in the PA variable (regression model 1 - RM1), and which body measurements explain the largest amount of variation in the PH variable (regression model 2 - RM2, Figure 5.1). A Pearson correlation was conducted to determine if a straight-line correlation exists between PH and body length (BL); chest depth (CD); hip height (HH); hindquarters width (HW); rump length (RL); shoulder height (SH); variables entered into RM2 (Havlicek & Peterson, 1976). As can be seen from Table 5.4, there was a positive relationship between PH and all the body measurements, although CD had the biggest effect. Basarab *et al*. (1993) reported that heifers' PH was of no value for prediction of dystocia and accounted only for five percent of the explained variation in calving ease.

P-Plots and histograms (Osborne & Waters, 2002), as shown in Figures 5.1 to 5.2, were used in order to check for normal distribution of errors in the regression models. From the P-Plots and histograms in Figures 5.1 and 5.2, it can be seen that the residuals are more or less normally distributed. P-Plots more or less form a straight line and histograms display a bell curve. This means that the residuals in both regression models are normally distributed.

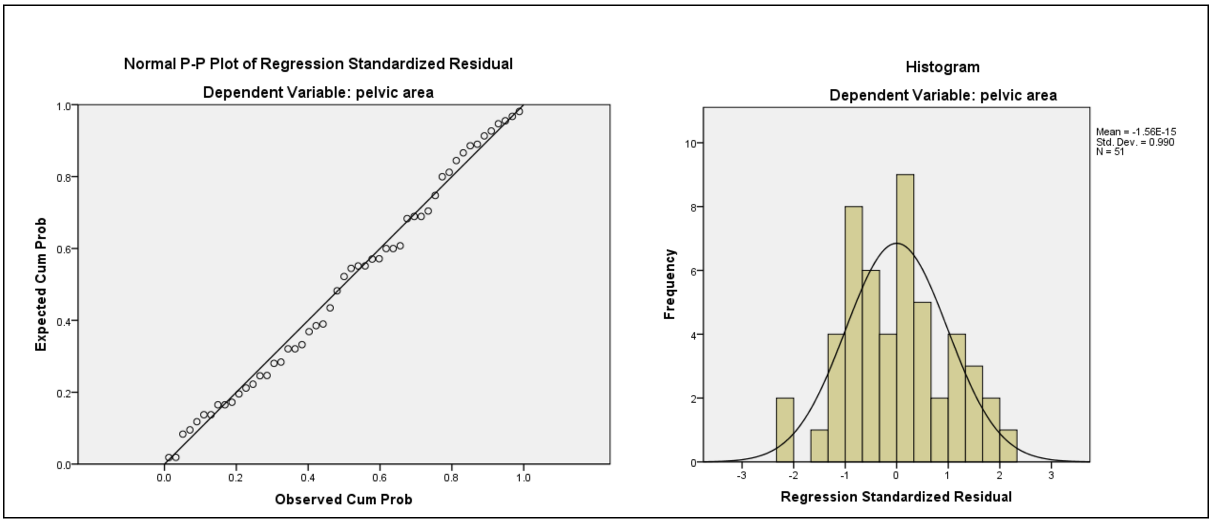

Figure 5. 1: P-Plot of regression standardised residual for RM 1 (left) and Histogram of regression standardised residual for RM 1 (right)

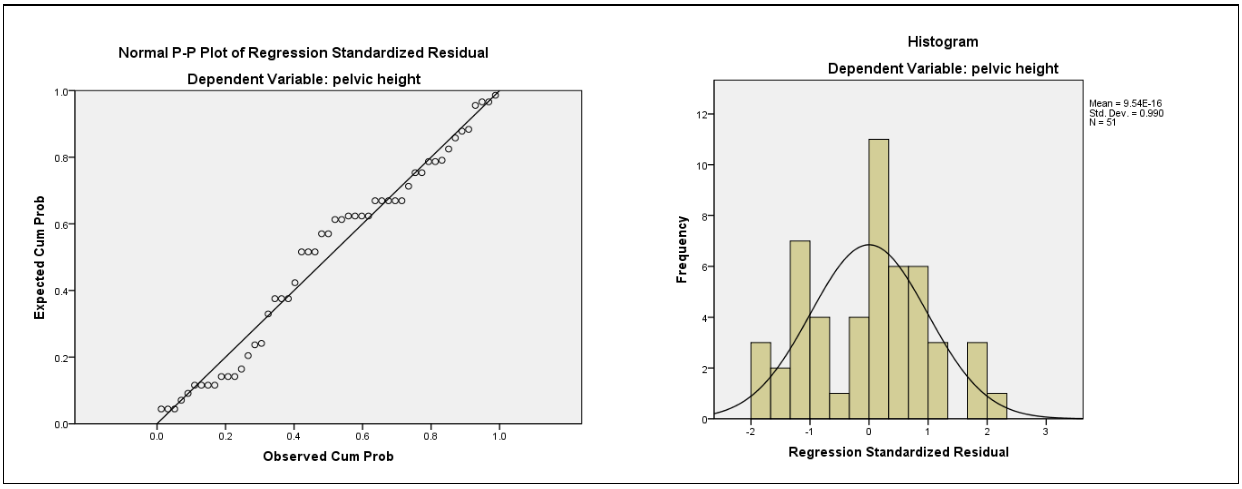

Figure 5. 2: P-Plot of regression standardised residual for RM 2 (left) and Histogram of regression standardised residual for RM 2 (right)

In order to investigate homoscedasticity of the regression models, the scatterplots of the residuals of the independent variables by the predicated value were investigated. In Figure 5.3 and Figure 5.4 it can be seen that not only is the fit line very flat, but the spread of the residuals also does not increase or decrease as you move across the predicted values. In other words, residuals do not fan out in a triangular fashion. This means that there is an equal variance of errors across all levels of the independent variables for both regression models.

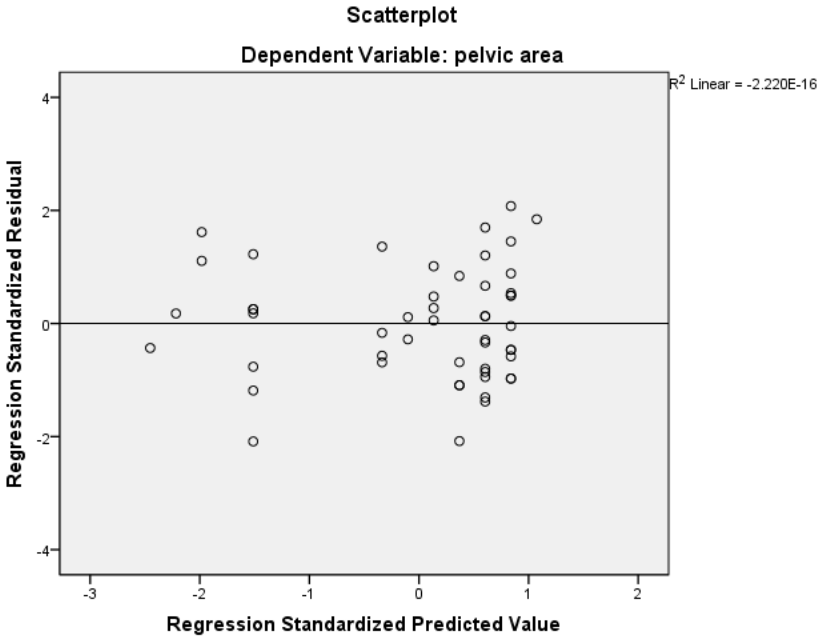

Figure 5. 3: Scatter plot of standardised residuals vs. the unstandardised predicted values of the independent variables collectively for RM 1

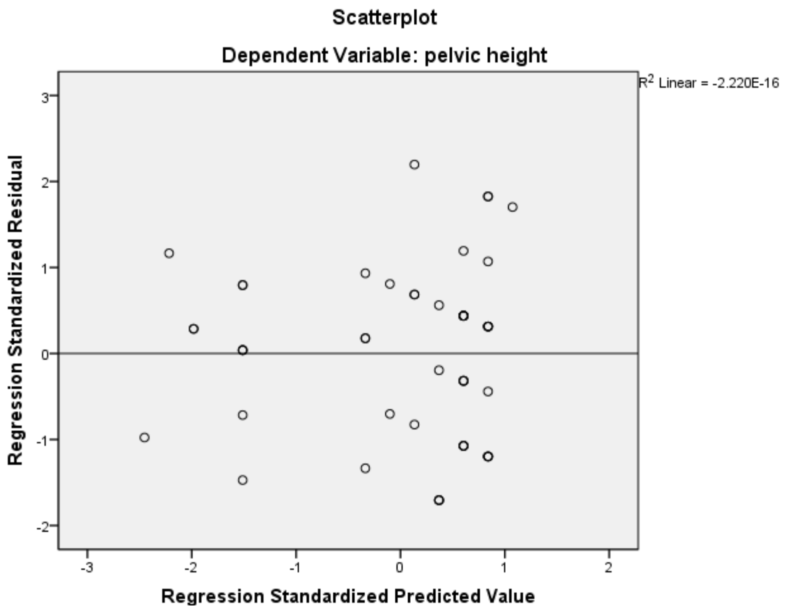

Figure 5. 4: Scatter plot of standardised residuals vs. the unstandardised predicted values of the independent variables collectively for RM 2

5.3 Multiple regression

Stepwise multiple regression was selected for this study, as it is particularly suitable to answer the question of what the best combination of independent variables to predict the dependent variable are (Field, 2009). In a stepwise regression, not all independent variables may end up in the equation. Independent variables are entered into the regression equation one at a time. At each step of the analysis, the independent variable that contributes most to the prediction equation in terms of increasing the multiple correlations, R, is entered first (Norman, 2010). This process is continued only if additional independent variables add statistically to the regression equation. When no additional independent variables add anything statistically meaningful to the regression equation, the analysis stops (Field, 2009).

5.3.1 Multiple regression for pelvic area (PA) variable (RM1)

A stepwise multiple regression was conducted to evaluate whether all body measurement variables, namely body length (BL); chest depth (CD); hip height (HH); hindquarters width (HW); rump length (RL) and shoulder height (SH) were necessary to predict the pelvic area (PA) variable. Only the chest depth (CD) variable made a statistical contribution to the model and was entered into the regression model. This resulted in a significant model $R^2 = 0.357$, $F (1,49) = 27.23$, $P < 0.001$; adjusted $R^2 = 0.344$. The adjusted R^2 value of 0.344 indicates that approximately 34% of the variability in the PA variable could be predicted by the CD variable. Van Nieuwenhuizen *et al.* (2017) reported that the increase in body measurements is related to an increase in pelvic dimension. This applies to body length, heart girth, shoulder height and age of the heifer in their study, meaning that the relationship between pelvic dimension and body measurements are still unclear for Brahman, Nguni and Bonsmara cattle breeds. These findings are in agreement with the current study using the Sussex cattle breed, as it is only chest depth, with a moderate contribution in variability of approximately 34% in the PA, that could be predicted by the chest depth.

The following guidelines, presented by Evans (1996), were used to interpret R^2: very weak (0-4%); moderate (16-36%); strong (36-64%) and very strong (64-100%). From these guidelines, it can be seen that the model that was constructed had a moderate predictive power towards the PA variable. The practical implication of this finding it that the regression model that was developed provides good insight into what was provided by the regression model which complete sentence with the practical implication of this finding. The only predictor of PA was the chest depth (β = 0.598) variable.

The coefficients' table of the regression model is shown in Table 5.5. This table was used to construct the regression equation for predicting the PA variable:

Predicted Pelvic Area = (2.345 x Chest Depth) + 66.55

Table 5.5: Model coefficients for regression model of PA variable

Game constructs	B	SE	B	t	p
Constant	66.55	30.37		2.192	0.033
Chest Depth	2.345	0.449	0.598	5.218	0.001

5.3.2 Multiple regression for pelvic height (PH) variable (RM2)

A stepwise multiple regression was conducted to evaluate whether all body measurement variables namely body length (BL); chest depth (CD); hip height (HH); hindquarters width (HW); rump length (RL) and shoulder height (SH) were necessary to predict the pelvic height (PH) variable. Only the chest depth (CD) variable made a statistical contribution to the model and were entered into the regression model. This resulted in a significant model $R^2 = 0.220$, F (1,49) = 13.83, $P < 0.001$; adjusted $R^2 = 0.204$. The adjusted R^2 value of 0.204 indicates that approximately 20% of the variability in the PH variable could be predicted by the CD variable. The model that was constructed had a moderate predictive power towards the PH variable.

The practical implication of this finding it that the regression model that was developed provides good insight into what was provided by the regression model which complete sentence with the practical implication of this finding. The only predictor of PH was the chest depth (β = 0.469) variable. The coefficients' table of the regression model is shown in Table 5.6. This table was used to construct the regression equation for predicting the PA variable:

Predicted Pelvic Height = (0.082 x Chest Depth) + 12.48

Table 5.6: Model coefficients for regression model of PH variable

Game constructs	B	SE	B	t	p
Constant	12.48	1.486		8.400	0.001
Chest Depth	0.082	0.022	0.469	3.719	0.001

5.4 Conclusion

Pelvic area measurements, birth weight and gender of the calf are the most important parameters in predicting dystocia. It can also be concluded that PH plays a bigger role in PA compared to PW in predicting dystocia. The relationship between external body measurements and pelvic dimension seems to be unclear, as it is only chest depth that can be used for purposes of predicting PA. Further studies on the relationship between certain body measurements and pelvic dimensions on different cattle breeds are recommended.

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CHAPTER SIX

GENERAL CONCLUSIONS & RECOMMENDATIONS

6.1 Conclusions

The aim of this study was to use pelvic area measurements and external body measurement in the selection of replacement Sussex heifers to reduce dystocia amongst heifers at parturition, while improving their ease of calving. The results of this study used two types of analysis; correlation matrix and PCA, to indicate that PA measurements measured prior to mating have a moderate significance when sex and BW of the calves are included in the analysis. This was as a result of the fact that heifers were more prone to dystocia when they calved males. One of the objectives of this study was to determine the relationship between PA, pelvic dimensions and dystocia. In overall, it can be concluded that there is a high significant relationship between PA dimensions in first calving Sussex heifers. It can also be concluded that PH plays a bigger role in PA compared to PW in predicting dystocia.

Pelvic area measurements, BW and gender of the calf are the most important parameters in predicting dystocia. Pelvic area measurements must be calculated accurately in order to eliminate heifers with small PA to reduce dystocia, since these parameters seem to be the most important factors that influence dystocia in many herds. Another objective of this study was to evaluate the relationship between pelvic dimensions and body measurements (pre-breeding) in predicting dystocia in two-year-old heifers. The results revealed that the relationship between external body measurements and pelvic dimension seems to be unclear, as it is only chest depth that can be used in predicting PA.

6.2 Recommendations

Based on the above conclusions, the following recommendations are forwarded:

- ✓ Every beef farm owner/manager should implement a dystocia monitoring program and employ management practices that limit the occurrence and impact of dystocia.
- ✓ Education of beef producers on the management and strategies to reduce dystocia and its effect on calves should be a priority.
- ✓ Sussex farmers should select the appropriate size of sire to that of dams at the time of breeding and avoid breeding heifers at younger ages.
- ✓ Pelvic area measurements must be taken prior to breeding and calculated accurately in order to eliminate heifers with small PA to reduce dystocia in many herds.

- ✓ I will recommend that a follow-up study be undertaken in which the ease of calving is determined in dams that have been measured for pelvic size.
- ✓ Further studies on the relationship between certain body measurements and pelvic dimensions are recommended.