

CHAPTER 1 INTRODUCTION

1.1 Background

Rupture of the cranial cruciate ligament (RCCL) is one of the most common causes of hind limb lameness in the dog (Bennet et al 1988, Ness et al 1996, Conzemius et al 2005). In the United States of America, an estimated \$1.32 billion was spent on the treatment of RCCL in dogs in 2003 alone (Wilke et al 2005). In a study of South African veterinary practices, cruciate surgeries comprised 8.23% of the total caseload during one year, 26.2% of all orthopaedic cases seen, making it a canine orthopaedic condition with huge economic impact (Van Niekerk et al 2002). Cranial cruciate ligament instability in dogs is now generally accepted to be a degenerative condition, usually involving both femorotibial (stifle) joints to some degree, with an acute episode resulting in the ultimate failure of the ligament under strain (Johnson et al 1993).

Various methods of joint stabilization or ligament repair are used in practice (Ness et al 1996, Conzemius et al 2005, Metelman et al 1995), but there is no significant difference in outcome between the different surgical techniques, with an average of 13.6% dogs regaining normal limb function, and clinical improvement seen in 29.7% to 80% of dogs, depending on the criteria used to determine improvement (Ness et al 1996, Aragon et al 2005, Conzemius et al 2005). Several factors have been considered as contributing factors to the high incidence of persistent lameness following cruciate repair surgery. These include age, body weight, sex, pre-surgical chronicity of the injury, degree of radiographic degenerative joint changes and the presence of meniscal injury. None of these factors have reliably been shown to be statistically significant (Metcalf et al 1995, Conzemius et al 2005).

Dogs with chronic stifle pathology often have a history of intermittent episodes of variable duration during which they carry the affected limb in a flexed position against their abdomens. Other dogs present with a decreased stifle angle (stifle extension), which

results in an obligatory compensatory decrease in hip angle (hip flexion) in order to keep the hind limbs positioned under the body (Bennet et al 1998). In the only study found which correlated stifle and hip dysfunction, Powers et al (2005) found that 94% of the dogs with CCL tears also showed signs of hip joint pathology. In most of these cases the researchers were unable to verify an orthopaedic cause for the pain at the hip joint, either radiographically or arthroscopically. This suggests that soft tissue structures such as muscles may be involved.

There is no data available on what would constitute a clinically significant reduction in hip extension in terms of the dog's gait pattern. Various force plate studies have based their conclusions regarding limb function in cruciate deficient limbs on the reduction in peak vertical force generated by the affected limb as compared to the unaffected limb (Ness et al, 1996). The portion of the canine stride cycle responsible for generating peak vertical force is the second half of the stance phase, the 'push-off' phase, which begins as the dog's body weight passes over the hind limb in a vertical position. At this point in the stance phase, the net ground reaction force generated is in the direction of the dog's linear progression. Therefore peak vertical force will be reduced if there is a limitation that affects the second half of the stance phase, from neutral hip position to the point caudal to neutral where the limb loses contact with the ground and protraction of the limb starts.

1.2 Problem Statement

Many dogs seen by the researcher for rehabilitation of CCL injuries have limited hip extension on the affected side, a factor that limits the patient's rate of return to normal gait. The probability that this is due to long term compensation for chronic pain is greater than the possibility of it being a factor induced by the surgery, as pain management post surgery is generally good, and the confinement short-term. A reduction in hip extensor range of motion has not yet been assessed as a factor in the failure of cruciate repair surgery. So it is worth establishing if limited passive hip extension range is a consistent finding in dogs with cranial cruciate ligament insufficiency.

1.3 Significance of the study

If compensatory hip flexion in dogs with cranial cruciate ligament instability, either long-term or acute, results in a shortening of the muscles responsible for hip flexion, and therefore a reduction in the range of hip extension, it will limit the dog's return to normal gait. If this hypothesis holds true, appropriate rehabilitation protocols aimed at improving hip extension range will improve the outcome of surgical treatment in these cases. Considering the possible economic impact of canine cruciate ligament disease, it is important to improve treatment outcomes in every way possible.

1.4 Aims of the Study

1. To determine the angle of hip extension required for normal trotting gait (1.5 – 2m/s) in dogs of the gundog and working groups.
2. To determine whether canine cranial cruciate ligament instability is associated with a significant decrease in hip extension range; that is, a reduction in hip ROM (range of motion) severe enough to result in a visible reduction of weight bearing hip extension during gait as measured videographically.

1.5 Objectives

The objectives of this study are to:

- a) Determine the degree of hip extension at the end of the stance phase of stride of a clinically normal dog.
- b) Determine the presence of a limitation in hip extension in cranial cruciate deficient dogs.
- c) Determine whether there is a significant difference in mean limitation in hip extension between the cranial cruciate ligament deficient and normal dogs.

- d) To determine whether such a limitation of hip extension, if present, constitutes a difference significant enough to have an effect on gait.

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

In this literature review, the background that led to this study will be discussed. The incidence and economic impact of canine cruciate ligament rupture will be outlined. The anatomy and pathology behind rupture of the canine cranial cruciate ligament will be described, as well as current concepts in its diagnosis and treatment, both surgically and conservatively. Brief attention will also be given to the anatomy and pathology of the canine hip as it relates to the knee, due to the mechanical relationship between these two joints.

2.2 The Canine Ruptured Cranial Cruciate Ligament

2.2.1 Definition

Cranial cruciate ligament ruptures in the canine occurs when the breaking strength of the cranial cruciate ligament, the primary stabilizer of the stifle during extension and rotation, is exceeded (Johnson & Johnson 1993). Either complete rupture with gross instability or partial rupture with minor instability of the stifle (femorotibial) joint occurs. Both scenarios result in progressive degenerative changes in the affected joint (Piermattei & Flo 1997).

2.2.2 Incidence and Economic Impact

Commonly seen in veterinary practice, rupture of the cranial cruciate ligament (RCCL) in dogs is a major cause of canine morbidity and comprises a large portion of the money spent in the veterinary industry each year (Wilke et al 2005, Bennet et al 1988, Ness et al 1996, Conzemius et al 2005). Surgery is the treatment of choice, and although many

different techniques exist, the rate of return to pre-injury level of function is as yet unsatisfactory, with only an average of 30% of surgical cases regaining normal function (Ness et al 1996, Conzemius et al 2005, Metelman et al 1995). An analysis of canine anatomy shows a distinct relationship between the stifle and the hip of the dog (Pasquini et al 1998, Bennet et al 1998). This correlates with the author's observations in practice that stifle pathology is often associated with loss of function at the hip.

Rupture of the cranial cruciate ligament (RCCL) is one of the most common causes of hind limb lameness in the dog (Bennet et al 1988, Ness et al 1996, Conzemius et al 2005). In a survey done by Ness et al (1996) of the British Veterinary Orthopaedic Association, cruciate ligament injury was among the top ten most common conditions diagnosed. In their study, 41.6% of diagnoses were related to joint disease, specifically arthritis, and the next largest diagnosis category was ligament injuries, of which cruciate ligament injury was the primary diagnosis. The only South African figures available are from a survey done of the surgical caseloads of private and academic veterinary hospitals in 1990 (Van Niekerk et al 2002). This survey found that of the 24.8% of orthopaedic and surgical cases seen, 8.23% were cruciate ligament repairs. Private practices saw significantly more of these cases, 6.5% as compared to the 1.73% seen in the academic hospital. In private practice, cruciate surgery was the most common elective orthopaedic surgical procedure performed, and the fifth most frequently performed surgery in total. This study does not give any indication of the number of cruciate ligament instabilities treated conservatively, but it does indicate that these type of injuries have a very high incidence in South Africa.

In a study by Wilke et al (2005) in the United States of America, specialist veterinary surgeons and general practitioner veterinarians practicing primarily on small animals were surveyed to estimate the economic impact of cranial cruciate ligament disease for dog owners in the USA. The purpose of this study was to motivate the prioritization of funding for research into cruciate ligament pathology. The mean number of ruptured cruciate ligament cases managed surgically per year was 215.4 (range 0 to 720), and the mean number managed medically per year was 36.1 (range 0 to 180). An estimated \$1.32

billion was spent on the treatment of RCCL in dogs in 2003 alone. The mean cost for a single surgery (\$1,840.50) was significantly higher than the mean cost for medical management (\$241.20).

The above authors (Wilke et al 2005) admit that their questionnaire was oversimplified, but this was offset by a high rate of return, as 36.5% of the survey population responded to the questionnaire. Nevertheless, cruciate ligament injuries were the second highest ranked diagnosis in first opinions and referral practice. The referral centres diagnosed a greater percentage of cruciate ligament injuries than arthritis, whereas first line practitioners diagnosed arthritis more frequently than cruciate ligament injuries. There may be two reasons for this. Firstly, it is likely that only dogs with suspected cruciate ligament injury are referred on to referral centres. The other possibility is that dogs with bilateral low grade chronic degeneration of the cruciate ligaments will also respond to conservative treatment for arthritis, namely pain control (non-steroidal anti-inflammatories), weight management and controlled exercise. Dogs that respond to this type of treatment regime may improve markedly, although there is a risk of complete rupture of the cruciate ligament at a later time.

2.3 Overview of the Anatomy

2.3.1 Anatomy of the Canine Stifle Joint

The canine stifle is analogous to the human knee joint. The cranial cruciate ligament in the dog is the same functional structure as the anterior cruciate ligament of the human knee (see Figure 2.1). Both the human knee joint and the canine stifle joints are double condyloid joints with 2° of freedom of motion, namely *flexion/extension* and *internal rotation/external rotation*. The femoral and tibial articular surfaces are not congruent, as the femoral surface is significantly larger than the tibial surface. Therefore an accessory joint structure is required to augment stability of the joint. This function is performed by the medial and lateral *menisci* of the knee. The menisci are semicircular

fibrocartilagenous discs that form concavities into which the femoral condyles fit. The lateral meniscus in both species is fairly mobile, but the medial meniscus is firmly attached to the tibia as well as the medial collateral ligament, making it more vulnerable to tearing during shearing forces of the femoral condyle on the tibial plateau (Norkin & Levangie 1992; Pasquini et al 1998; Piermattei & Flo 1997; Riegger-Krugh & Millis 2000).

The function of the ligaments of the knee/ stifle joint is to resist excessive movement of the joint. These movements include excessive extension, varus and valgus stresses at the knee, anterior or posterior displacement of the tibia beneath the femur, and medial or lateral rotation of the tibia beneath the femur (Norkin & Levangie 1992; Piermattei et al 1997)

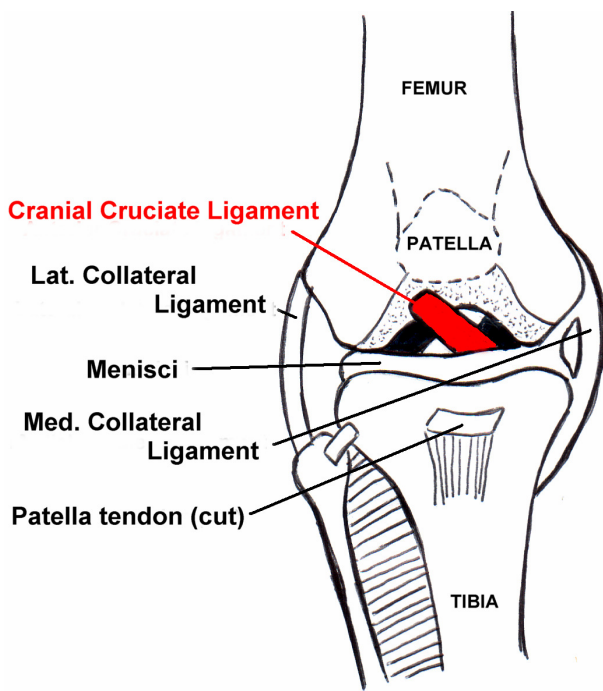


Fig 2.1a: Human Knee Joint

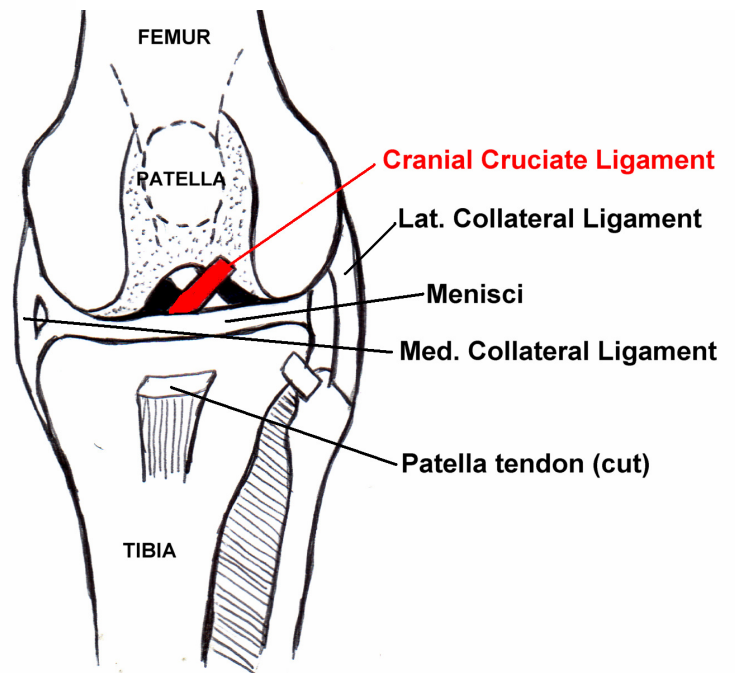


Fig 2.1b: Canine Stifle Joint

In both dogs and humans, medial and lateral collateral ligaments are described. In the human, the medial collateral ligament resists valgus stresses across the joint, checks lateral rotation of the tibia and acts as a backup restraint to anterior displacement of the tibia in cases where the primary restraint of the anterior cruciate ligament is absent (Norkin & Levangie 1992). Its function is less well described in the dog, but in both species the medial collateral ligament fuses with the joint capsule and the medial meniscus, contributing to the immobility of the medial meniscus (Norkin & Levangie 1992, Pasquini et al 1998; Riegger-Krugh & Millis et al 2000). The lateral collateral ligament resists varus stresses across the knee, as well as lateral rotation and posterior displacement of the tibia. It is separated from the lateral meniscus by the tendon of the popliteus muscle, and has no attachment to the joint capsule (Norkin & Levangie 1992, Pasquini et al 1998; Riegger-Krugh & Millis 2000). In the human knee, the *iliotibial band* is also described as a passive restraint of the knee, assisting the anterior cruciate ligament in limiting posterior displacement of the femur on a fixed tibia with the knee in extension (Norkin & Levangie 1992).

The human knee contains an anterior and posterior cruciate ligament. The canine stifle joint contains comparative structures namely the cranial and caudal cruciate ligaments, which perform similar functions to their counterparts in the human. In both species the cruciate ligaments lie outside the synovial membrane of the knee joint (Norkin & Levangie 1992, Pasquini et al 1998; Riegger-Krugh & Millis 2000). For the scope of this study, this anatomy discussion will concentrate only on the cranial cruciate ligament. The anterior / cranial cruciate ligament attaches to the cranial aspect of the tibia, and extends posteriorly/ caudally to the inner aspect of the caudolateral part of the femoral condyle. It is the primary restraint to anterior/ cranial translation of the tibia relative to the femur and also plays a role in controlling excessive medial rotation of the tibia (Norkin & Levangie 1992, Pasquini et al 1998; Riegger-Krugh & Millis 2000).

2.3.2 *Anatomy of the Hip Joint*

The canine stifle joint, like most structures in the body, does not function in isolation. Important anatomical and functional interrelationships exist between the stifle and the hip joint of the dog. In a study on canine hind limb lameness by Powers et al (2005), 94% of the dogs in the study had concurrent signs of stifle and hip pathology. No other study was found that examined the presence of hip pathology associated with stifle pathology.

Structures that relate to both these joints are several muscles, as well as the nerves of the pelvic limb. However, this discussion will limit itself to an overview of the muscles acting over both the hip and the stifle, as these provide a functional relationship between the two joints. Consequently, functional impairment at one motion segment, in this case the stifle joint, will lead to dysfunction at the hip as it will be shown that these two joints can not be viewed as separate functional entities.

In the dog, muscles that act over both the hip joint and the stifle joint are the rectus femoris, semitendinosus, semimembranosus, biceps femoris, sartorius, gracilis, and the tensor fascia lata- iliotibial band tract – seven muscles in all (Pasquini et al 1998). The presence of two-joint muscles is a very significant biomechanical factor. Two joint muscles are subject to both *active and passive insufficiency*. The term *active insufficiency* refers to the phenomenon that two joint muscles cannot contract maximally over both the joints that they cross. *Passive insufficiency* refers to the opposite, where a two-joint muscle cannot lengthen maximally over both the joints it crosses (Norkin & Levangie 1992). The result of this is that any pathology at the stifle that affects the extensibility of the muscles mentioned above, affects the range of motion at the hip joint, and any inhibition of muscle contraction at the stifle will increase the contraction of the relevant muscle at the level of the hip during co-contractions of the muscle.

2.3.3 *Two-joint Muscles of the Hip and Stifle*

The dog with a ruptured cranial cruciate ligament presents with either a non-weight-bearing lameness, keeping the joints of the hindlimb in a hyperflexed position, or with a

lameness characterised by an increased extension angle at the stifle joint and a compensatory increased flexion angle at the hip joint (Johnson & Johnson 1993, Piermattei & Flo 1997). Chronic stifle pathology therefore results in repetitive hip flexion/ stifle flexion, or repetitive hip flexion/ stifle extension. According to Pasquini et al (1998), the action of the sartorius muscle causes flexion of the hip as well as flexion of the stifle, therefore shortening of this muscle at both joints could occur with chronic non-weight bearing lameness. Two-joint muscles that cause flexion at the hip while extending the stifle joint are the rectus femoris muscle and the tensor facia latae muscle (Pasquini et al 1998). Pain inhibition of the extension component of these muscles at the stifle joint and an associated increase in hip flexion angle will also cause shortening of these muscles at the hip.

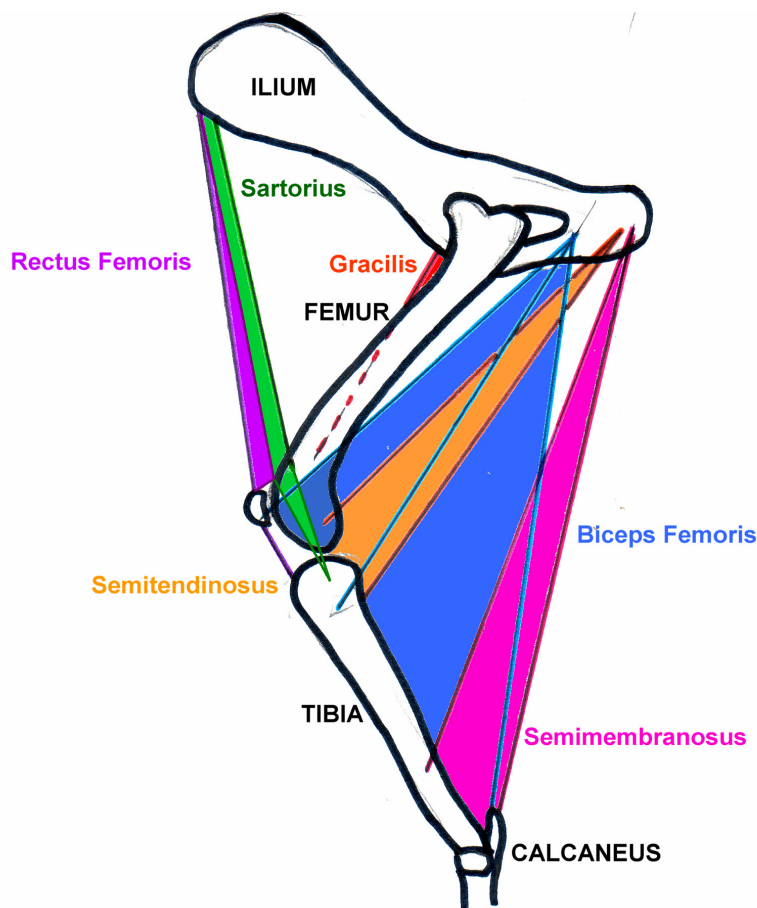


Fig 2.2: Diagrammatic representation of the muscles of the canine hind limb

Table 2.1: Two joint muscles of the stifle that also result in hip flexion

MUSCLE	ORIGIN	INSERTION	ACTION	INNERVATION
M Rectus femoris	Ilium	Patella and tibial tuberosity	Flexion of the hip Extension of the stifle	Femoral n.
M Sartorius	Ilium	Medial side of stifle	Flexion of the hip Flexion of the stifle	Femoral n.
M Tensor fascia latae	Tuber coxae	Lateral femoral fascia	Flexion of the hip joint Extension of the stifle	Gluteal n.

(modified from Pasquini et al 1998)

2.3.4 The lumbopelvic/hip complex

Central to this study was the measurement of hip extension range of motion. However, both the ilium and the femur have important relationships to the spine which require further discussion, as they impact on the validity of the hip extension measurements taken.

The Iliopsoas muscle consists of the Psoas major muscle, originating from the lumbar vertebrae, as well as the Iliacus muscle, originating from the medial surface of the wing of the ilium. Both these muscles have a common insertion onto the lesser trochanter of the femur. The function of the Iliopsoas is to flex and slightly externally rotate the hip (Pasquini et al 1998). Therefore, when the hip joint is taken into full, non-weight-bearing extension, passive insufficiency of the lumbar portion of Psoas major will result in a certain degree of lumbar extension, which is readily palpable when performing this motion (Edge-Hughes 2007). If the lumbar spine was stabilised in a manner that would

prevent this ventral curvature in response to tension on Psoas major, the increased resistance in this portion of the muscle would restrict the amount of hip extension available.

Furthermore, an important connection between the ilium and the sacrum exists through the action of the sacrotuberous ligament which extends from the sacrum and the first caudal vertebrae to the ischiatic tuberosity (Pasquini et al 1998). The tension in this ligament influences the amount of nutation and counternutation possible in the sacrum, which in turn influences the dorsoventral excursion of the lumbar spine (Norkin & Levangie 1992). Therefore, while the position of the ilium does not directly affect the amount of movement in the coxofemoral joint, it may affect the position of the sacrum and lumbar spine, which in turn affect tension in Psoas major. Through this mechanism, hip extension range will be indirectly influenced.

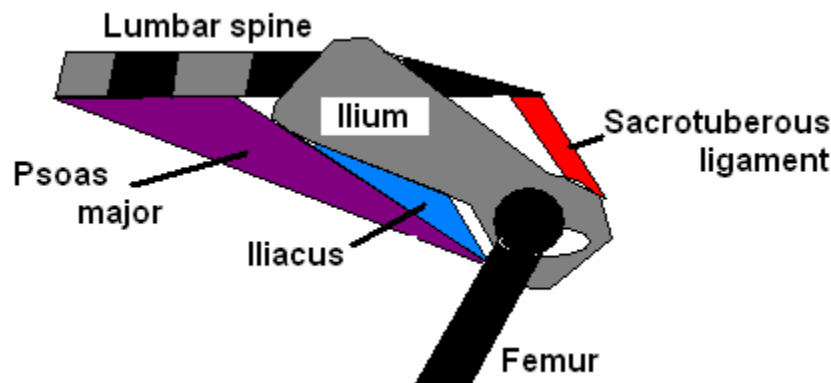


Fig 2.3: Diagram showing important functional relationships between the lumbar spine and the femur

It should be possible to stabilise the lumbar spine to prevent any motion artifacts at this level from affecting range of motion at the hip. However, it would be necessary to determine which position of the lumbar spine is neutral relative to the hip, and this position would need to be accurately repeatable on multiple individuals with potentially varying morphology. Jaegger et al (2002) did not stabilise the spine during their

measurements of hip joint range of motion, simply taking up all the available slack in the opposing soft tissue structures to obtain their data. The measurement techniques described by these authors were very reliable, if not entirely valid due to poor localisation of the joint motions tested. The method utilised by Jaegger et al (2002) is, to date, the most accurate way of determining hip extension range. However, data acquired through this method should be assumed to involve the lumbopelvic motion segments as well as the hip joint, and should not be viewed as pure hip extension range.

2.4 *Aetiology of RCCL*

Cranial cruciate ligament instability in dogs is now generally accepted to be a degenerative condition, usually involving both femorotibial (stifle) joints to some degree, with an acute episode resulting in the ultimate failure of the ligament under strain. No specific breed or size of dog appears to have a greater predisposition to cruciate ligament ruptures, however it appears to occur mostly in dogs between the ages of 4 to 6 years of age, and obesity is a definite risk factor (Johnson & Johnson 1993). As the ligament ages, there is a reduction in both the quantity and quality of the fibroblasts in the ligaments. This degeneration has been shown to be worse in dogs that weigh more than 15 kilogrammes, indicating that weight plays a role in its development. Dogs that are inactive are also more prone to degeneration of the cranial cruciate ligament. This degeneration is usually present bilaterally.

There are two mechanisms through which the cruciate may rupture acutely. As the primary stabiliser during extension and internal rotation, hyperextension and excessive rotation of the stifle could exceed the braking strength of the ligament. Another mechanism which is perhaps more common, is perpetual overloading of the cranial cruciate ligament as it opposes anterior translation of the tibia during contraction of the gastrocnemius muscle. Sudden forceful contractions of the gastrocnemius, such as occurs during jumping, can overload the ligament, resulting in partial rupture, particularly if there is pre-existing degeneration of the ligament. Additional biomechanical problems

such as maltracking of the patella mechanism will increase the risk of degeneration and rupture. Other factors that may contribute to degeneration of the ligament are immune-mediated disease processes within the joint and joint infections (Piermattei & Flo 1997). Most authors agree that cruciate ligament injury and degenerative changes in the stifle are related. Instability of the stifle joint leads to inflammatory processes that ultimately result in destruction of articular cartilage and osteophyte formation (Johnson & Johnson 1993).

2.5 *The consequences of restricted joint mobility*

When a joint is not used throughout its full available range of motion, or is immobilized, for a prolonged period of time, several changes occur in the structures of which the joint is comprised. These changes include the proliferation of fibrofatty connective tissue into the joint space and the formation of adhesions of these fibrofatty deposits to the surface of the joint cartilage. Atrophy of the cartilage occurs, and water and proteoglycan content of the cartilage is reduced. Ligament collagen fibres become disorganized in their arrangement, and the ligaments also lose water and proteoglycan content, reducing their extensibility. There is destruction of the ligament fibres at the attachment of the ligament to the bone (Sharpey's fibres), due to osteoclastic activity, as well as regional osteoporosis of the bones of the joint (Norkin & Levangie 1992).

2.6 *Diagnosis*

2.6.1 *Diagnosis of CCL pathology*

The clinical history of the cruciate deficient stifle is usually one of an acute incident resulting in a non-weight bearing lameness lasting several days, after which the dog will normally start to use the limb again and continue to progress over several weeks. However, this apparent improvement is followed by an acute or gradual decline in limb usage due to pain caused by secondary meniscal damage. Lameness is characterised by a

reduction in extension angle at the stifle joint and, according to some authors, a reduced caudal stance phase of the stride cycle (Johnson & Johnson 1993, Piermattei & Flo 1997). However, Madore et al (2007) found that caudal stance phase was not greatly affected in dogs with CCL insufficiency.

Assessment of the cruciate deficient stifle in the dog is based on clinical history, observation of gait, pain and/or crepitations on motioning of the stifle, the presence of a medial buttress, and a positive cranial drawer sign or tibial thrust test (Bennet et al 1988, Johnson & Johnson 1993). Radiographs will confirm the presence of degenerative changes in the affected joint or joints. Meniscal damage is often present, but is usually only confirmed on arthrotomy or arthroscopically. Manual tests for meniscal tears exist in human orthopaedic assessment (Brukner & Kahn 1999), and have also been described in animal physiotherapy literature (Edge-Hughes 2007). However, no veterinary texts could be found that include these tests for meniscal tears, and they are not widely taught or performed in veterinary orthopaedic assessments.

2.6.2 Hip pathology as differential diagnosis for hind limb lameness

Other structures of the pelvic limb, such as the hip joint, are assessed with the purpose of excluding joint degeneration and laxity. When hip pathology occurs in the older dog (over 15 months of age), it is usually due to pain caused by the degenerative changes following hip dysplasia. The dog tends to be lame with a waddling pelvic gait, particularly after heavy or prolonged exercise, and crepitus is palpable in the hip joint, and may be audible through a stethoscope held against the joint. The dog rises with difficulty, and atrophy of the gluteal and thigh muscles is often marked. Radiography is used to establish a positive diagnosis. There are several hip dysplasia scoring systems in use across the world. In South Africa, the standard KUSA (Kennel Union of South Africa) grading system classifies hip dysplasia into five (5) categories based on the degree of flattening of the femoral head, and subluxation of the femoral head from the acetabulum (Piermattei & Flo 1997; Kirberger 2007). Radiographs are taken in a dorsoventral view with the hips in extension. In many cases, routine radiographs are not

taken in cases of suspected cruciate ligament pathology. The reason for this is the additional expense involved. In standard practice in Johannesburg, South Africa, a first radiograph will cost R120,00, and subsequent radiographs cost R95,00 each (South African Veterinary Association Pricing Guidelines 2007).

2.6.3 Assessment of two-joint muscle flexibility

In the human patient, assessment of muscle and soft tissue flexibility form an intergral part of the evaluation of the lower limb. Specific tests have been developed to assess the flexibility of two-joint muscles, such as the Thomas test for shortening of the iliopsoas muscle, and the Ober test for shortening of the tensor fascia latae-iliotibial band complex. Flexibility of the hamstrings, adductors and gastrocnemius muscles are also routinely tested in all cases of lower limb joint pain and/ or dysfunction (Donatelli 1989). No similar assessments for canine pelvic limb dysfunction are described in the literature.

2.7 Goniometric measurements of the hip and stifle

Many studies have been done showing the reliability and validity of goniometry in human rehabilitation medicine (Hamilton & Lachenbruch 1969; Boone et al 1978; Gajdosik & Bohannon 1987; Goodwin et al 1992). In 2002, Jaegger et al did a study that showed that goniometry was also a valid, reliable measuring tool in the assessment of Labrador Retriever dogs. As it is also non-invasive, cheap and clinically useful, it is therefore the measurement tool of choice in determining the hip extension angles of the dogs in this study. Jaegger et al (2002) measured average joint ranges in a group of normal, healthy Labrador Retrievers. They found that normal full passive hip extension range in an adult, healthy Labrador Retriever was 162° (SD +/-3). Other important findings of this study were that there was no significant difference between measurements done with the dogs awake and the dogs sedated, and that the inter-rater reliability when measuring hip joint range of motion was good ($P < 0.01$).

2.8 *Canine body condition scoring*

Obesity in dogs is strongly associated with the incidence of various orthopaedic conditions including CCL pathology (Johnson & Johnson 1993; Piermattei & Flo 1997). A commonly used assessment of whether a dog's weight is appropriate is the 5 point Body Condition Score, an example of which is published by Hill's Pet Nutrition (www.cathelp-online.com/health/b.score/bhp, 2007). According to this scoring system, a score of one (1) denotes a dog that is very thin, five (5) denotes a dog that is obese, and three (3) refers to a dog that is considered to be at its ideal weight. The definitions of each of the scores are given in Appendix A.

2.9 *Analysis of the Canine Gait with particular focus on the Hindlimb*

There are several methods that are used to study gait in the dog. A description of some of them follows.

2.9.1 *Videographic studies*

A study by Colborne et al (2005) measured joint angles across the joints of the tarsal and stifle joints of normal healthy Labrador Retriever dogs during trotting gait. The hip was not included in their study. They placed reflective markers on specified bony landmarks on the dogs' hind limbs, and used four cameras in tandem, to capture five stance phases, or four gait cycles, of gait.

2.9.2 *Force plate studies*

Force plates are widely used in canine gait research to determine mediolateral, craniocaudal and peak ground reaction forces generated during the stance phase of gait, but require specialised, expensive equipment (Budsberg et al 1987; Rumph et al 1994; Kapatkin et al 2007). Colborne et al (2004) studied the normal ranges and joint power for

the metatarsophalangeal joints, tarsus and stifle joints, but not the hip. Evans et al (2005) found force plate analysis to be an accurate and sensitive method of assessing lameness in Labrador Retrievers with CCL deficiency, while Conzemius et al (2005) used it to assess the improvement in gait after different CCL surgical repair techniques. A study by Madore et al (2007) compared several gait characteristics of dogs with stifle joint degeneration and dogs with hip joint degeneration. One of their findings was that dogs with stifle pathology showed a signature decrease in deceleration forces as opposed to acceleration forces during trotting gait. The acceleration force during the caudal part of stance phase was only slightly decreased in dogs with stifle arthritis.

2.9.3 Relating gait to anatomy

During the stance phase of gait, the pelvic limb comprises a closed kinematic chain. Movement in one segment of the limb influences and is influenced by movement in any other related segment. These segments include the lumbar spine, sacrum, pelvis, femur, tibia and tarsal complex. Proper function of these interrelated segments is dependant on their correct relative alignment. Once this proper alignment of segments is deranged, e.g. when gait is adapted to avoid pain, soft tissue deformation and changes in muscle length takes place (Donatelli 1989). This can lead to dysfunction in all of the joints that make up the kinetic chain of the pelvic limb. The interrelationship between the joints of the pelvic limb kinetic chain is influenced by muscles that act over two joints. In addition, the lumbar spine, pelvis and hip are connected by ligamentous structures (Pasquini et al 1998). These muscles are all affected adversely by pathology in the stifle, leading to dysfunction extending to the lumbar spine, hip and tarsus. However, passive range of motion at a joint does not necessarily reflect the degree of joint mobility required for functional movement i.e. gait. Various force plate studies have based their conclusions regarding limb function in cruciate deficient limbs on the reduction in peak vertical force generated by the affected limb as compared to the unaffected limb (Ness et al 1996). The portion of the canine stride cycle responsible for generating peak vertical force is the second half of the stance phase, the ‘push-off’ phase, which begins as the dog’s body weight passes over the hind limb in a vertical position. At this point in the stance phase,

the net ground reaction force generated is in the direction of the dog's linear progression. Therefore peak vertical force will be reduced if there is a limitation that affects the second half of the stance phase, namely neutral hip position in stance, when the dog is standing with its weight normally distributed over its four legs, that is 60% of its weight distributed between its front limbs, and 40% of its weight distributed between its hind limbs, to the point caudal to neutral where the limb loses contact with the ground and protraction of the limb starts. No videographic studies could be found examining the gait of dogs with CCL pathology.

2.10 Treatment

2.10.1 Current concepts in the treatment of canine RCCL

The aim of treatment of cruciate ligament ruptures is to limit the negative consequences of the joint instability on the cartilage and synovium, thereby reducing long-term morbidity. This means stabilising the joint as soon as possible, an aim most frequently achieved by surgical means. Various methods of joint stabilisation or ligament repair are used in practice. Conzemius et al (2005) compared three different surgical techniques for outcome in terms of limb function. The three techniques, lateral suture stabilization, intracapsular stabilisation and tibial plateau leveling osteotomy, vary significantly in degree of invasiveness, skill required by the surgeon and expense to the client. All the subjects in the above study were Labrador Retrievers, but they were not randomly allocated to surgical procedures, as this was ultimately the client's choice. According to these authors, there was no difference between the groups allocated to different procedures in terms of body weight, body condition score, age or duration of injury prior to surgery, but they do not support this statement with statistical analysis. Different surgeons were also used, but it is not stated whether all surgeons performed all the types of surgical procedures. Outcomes were measured using force plates to determine peak vertical force and vertical impulse. They found that only between 10.9% and 14.9% of the sample dogs regained normal limb function as compared to normal dogs. The authors

speculate that this may be due to pre-existing osteoarthritis in the joint or the removal of the torn medial meniscus. Metelman et al (1995) had previously also compared three different cranial cruciate ligament repair surgical techniques, but theirs was a retrospective study. Their study compared the outcome of these surgeries not in terms of limb function, but in terms of the necessity of a second surgery to remove a damaged meniscus. In the Metelman et al study, 13.8% of dogs that did not have a meniscectomy at the time of the initial surgery, returned for a second arthrotomy and meniscectomy. Their study has three shortcomings. Firstly, it is not known whether the meniscal damage found at the second arthrotomy was previously undiagnosed, or whether it occurred after the initial surgery, which would raise questions regarding the efficacy of the surgery in the first place. Secondly, the study does not describe the stabilisation techniques used in the second surgery following the meniscectomy. Thirdly, and perhaps most importantly, it does not have any follow-up results on the second surgery, therefore there is no indication of long term functional outcome in the dogs that had the meniscectomy. In summary, no significant difference in outcome has been shown between the different surgical techniques, with an average of 13.6% dogs regaining normal limb function, and clinical improvement seen in between 29.7% and 80% of dogs, depending on the criteria used to determine improvement. Several factors have been considered as contributing factors to the high incidence of persistent lameness following cruciate repair surgery. These include age, body weight, sex, pre-surgical chronicity of the injury, degree of radiographic degenerative joint changes and the presence of meniscal injury. None of these factors have reliably been shown to be statistically significant (Metcalf et al 1995, Conzemius et al 2005). Conservative management of cruciate ligament ruptures, consisting of weight and exercise management and medication to control inflammation and pain, is generally considered to be ineffective, especially in large breed dogs (Marcellin-Little 2005).

2.10.2 Human vs. Canine Cruciate Therapy Concepts

In human knee surgery, rehabilitation after surgery to repair instability due to ligament damage is standard practice, in order to restore a *functionally* stable knee with adequate

strength, flexibility and proprioception (Donatelli 1989). Reid (1992) goes as far as to say that patients with chronic anterior cruciate ligament (analogous to the cranial cruciate ligament in the dog) deficiency make poor candidates for surgery if they do not have the motivation to embark on a determined and comprehensive post-surgical exercise programme. Without rehabilitation, full function is rarely achieved.

Post-operative physiotherapy and rehabilitation protocols are becoming increasingly popular in small animal orthopaedics, although no studies have been done examining the efficacy of different treatment techniques or protocols. Many authors agree that rehabilitation aimed at reducing post-surgical pain and swelling, early passive range of motion exercises and muscle strengthening, usually through electrotherapy and hydrotherapy, are important factors in ensuring a good surgical outcome. The purpose of physiotherapy after cruciate surgery is to reduce the amount of muscle atrophy, loss of bone mass and weakening of the articular cartilage (Johnson & Johnson 1993; Francis et al 2006).

Rehabilitation protocols currently in place vary widely and no studies have been done to show whether any particular protocol ensures a statistically significant increase in success rate of cruciate ligament repair surgery. One study by Marsolais et al (2002) compared the outcome after six months of two groups of dogs, one rehabilitation group and one exercise restricted group. This was a well planned study, as all dogs had the same surgeon, same surgical technique and exactly the same rehabilitation protocol, consisting of massage, passive movements, controlled walking and swimming. The authors found that the rehabilitation group had a far greater increase in peak vertical force (PVF) and vertical impulse (VI) in the affected limb compared to the unaffected limb. The rehabilitation group also had little difference between their two pelvic limbs, while in the exercise restricted group there was a significant difference between the limbs (Marsolais et al 2002). No literature could be found that described assessment or treatment of the hip as part of canine CCL rupture rehabilitation.

2.11 Other studies investigating the effect of CCL pathology on the hip

No studies could be found in the literature that described the effect of CCL pathology on the biomechanics of the hip. The majority of the studies discussing CCL rupture focused primarily on the anatomical region of the femorotibial joint (Johnson & Johnson 1993; Bennet et al 1998; Piermettei & Flo 1997; Marsolais et al 2002; Francis et al 2006). The only study where hip pathology and CCL deficiency were correlated was done by Powers et al (2005), who found that 94% of dogs with CCL tears also showed signs of hip joint pathology. In most of these cases the researchers were unable to verify an orthopaedic cause for the pain at the hip joint, either radiographically or arthroscopically. These authors discussed only the incidence of concurrent pathology, without investigating the functional relationship between the two joints.

2.12 Conclusion

Rupture of the canine cranial cruciate ligament is a common problem seen in canine orthopaedic practice. Various surgical approaches are used in the treatment of these patients, but with varying degrees of successful functional outcome. There are several factors that can limit a dog's recovery after CCL injury, such as obesity, age, chronicity and co-existing pathology in other joints. The stifle joint is functionally related to the other joints of the hind limb. However, the effect of stifle pathology such as CCL rupture on the other joints of the hind limb, including the hip, has not been investigated. This is in spite of the fact that hip pain has been positively correlated with stifle pathology. The hip joint is functionally related to the stifle through the action of two-joint muscles, but few assessment or treatment approaches consider dysfunction at the hip joint when dealing with stifle pathology. In contrast, in the human patient the assessment of hip biomechanics forms a vital part of the assessment and rehabilitation process of cruciate pathology, and many tests exist to specifically assess the muscles affecting both the knee and hip.

During canine gait, pathology at the stifle affects function at the hip. Goniometric measurements of hip joint range of movement have been shown to be a valid and reliable measurement tool. Even so, in standard assessments of the cruciate deficient stifle, the only assessment regularly performed on the hip is radiographic evaluation to exclude hip dysplasia. Videographic studies of canine gait has been shown to be a useful way of assessing joint function of the pelvic limbs during gait, but previous studies have not included the hip joint in assessments of joint angles and joint moment. Videographic studies, along with force plate studies, are good assessment tools that provide much important data, but are not always practical in the clinical environment, as they can be expensive and time consuming.

3.1 Introduction

There are four components to this study. Each of the four steps of data collection was necessary to validate the next set of data, ultimately leading to a complete range of data that could be analysed to answer the central question of the study, the question of whether CCL pathology in dogs is associated with a significant reduction in hip extension. This chapter describes the composition of each of these groups, as well as how the data for each of these four parts of the study were collected.

The first of the four parts of the study was a pilot study performed in order to ascertain the intra-rater reliability of the measurements used to collect the data in this study. This was followed by the second part of the study, which was also a pilot study done to ascertain the inter-rater reliability of these same measurement tools. These first two steps were necessary to ensure the validity and reliability of these measurements tools, thereby providing for data sets that were accurate.

The first study population on which data were collected was a group of normal, healthy dogs. The data acquired for this group was necessary to determine normal values to which data collected for the CCL group could be compared.

3.2 Ethical considerations

The study only commenced once ethical clearance had been obtained from the Animal Ethics Committee of the University of the Witwatersrand. The ethical clearance number for this study is 2006/30/2A. The relevant ethical clearance form is attached in Appendix B. The nature and purpose of the study was explained to the owners of the dogs. The owners were asked to sign an informed consent form before the assessment was done.

3.3 Intra-rater reliability

3.3.1 Study design

A prospective, cross-sectional study.

3.3.2 Subjects

3.3.2.1 Number of dogs

Ten (10) dogs were included in this group. These same ten dogs formed part of the larger normal group studied in the third part of this study.

3.3.2.2 Inclusion criteria

This pilot study restricted its attention to healthy working and gundog group dogs as published by the Federation Cynologique Internationale (FCI) (www.fci.be/home, 2007), between the ages of 1 and 7 years old, weighing between 20 to 35kg, and with a body condition score of 2 to 4, as they have similar morphology and gait patterns.

3.3.2.3 Exclusion criteria

- Any history of lameness arising from a joint
- Any symptoms or signs of degenerative joint disease
- Any dogs currently on nutritional supplements designed to alleviate the symptoms of joint pain such as additives containing glucosamine, MSM (a natural supplement meant to aid joint mobility) or Devil's Claw (a natural anti-inflammatory nutrient).
- Any dogs that have been on a course of anti-inflammatory medication within the two weeks preceding assessment.

3.3.3 Measurements

Markers made of white self-adhesive paper dots of 3cm diameter were placed on the following bony landmarks (on each hind limb):

For the pelvic axis: A line connecting the midpoint between the cranial superior iliac spine and the caudal superior iliac spine, and the tuber ischii.

For the femoral axis: A line connecting the apex of the greater trochanter of the femur and the midpoint of the lateral femoral epicondyle. (Jaegger et al, 2002)

15s digital videoclips of the dogs' gait were taken with a *HP photosmart 753* digital camera, placed at the level of, and directly opposite the dog's coxofemoral joint, at a distance of 1m, with no zoom function used. These videoclips were downloaded onto a computer and digital images obtained at the point of the caudal stride phase just before the dog's foot leaves the ground. The angle between the two axes was obtained using siliconCOACH software (siliconCoach Ltd).



Fig 3.1: Example of computer generated maximum hip extension angle during gait

3.3.4 Procedure

3.3.4.1 Obtaining the data

Each dog had markers placed on the bony landmarks as described in Section 3.3.3 above. Each dog was then trotted on a level, straight surface at a pace of approximately 1.5 to 2m/s, past the camera which was mounted at the height of each dog's hip. Three passes were made past the camera to both sides with each dog. The videoclips were downloaded onto a computer and siliconCOACH software was used to obtain multiple hip extension values for each hind limb of dog. The average of these values was calculated and recorded as the mean hip extension range for each limb.

3.3.4.2 Determining intra-rater reliability

From ten (10) dogs twenty (20) hip extension measurements were obtained, one for each hind limb of each dog. Once all twenty measurements had been recorded, a second set of measurements was obtained from the same twenty videoclips, but in random order.

3.3.5 Data analysis

There was now one paired set of twenty data points consisting of two separate hip extension measurements for each limb. A one-way analysis of variance was then performed on these two data sets to determine the correlation between the groups.

3.4 Inter-rater reliability

3.4.1 Study design

A prospective, cross-sectional study.

3.4.2 Subjects

3.4.2.1 Number of dogs

Ten (10) dogs were included in this group. These same ten dogs formed part of the larger normal group studied in the third part of this study, but were not the same ten dogs used to determine intra-rater reliability.

3.4.2.2 Inclusion criteria

The inclusion criteria for this pilot study were the same as for section 3.3.2.2.

3.4.2.3 Exclusion criteria

The exclusion criteria in this pilot study were the same as for section 3.3.2.3.

3.4.3 Measurements

3.4.3.1 Videographic

The measurements for obtaining the videographic data for this part of the study were the same as in section 3.3.3.

3.4.3.2 Goniometric

Passive hip extension range was obtained using a 22cm goniometer. The same bony landmarks as described in section 3.3.3 were used to place the goniometer.

3.4.4 Procedure

Each dog had markers placed on the bony landmarks as described in Section 3.3.3 above. Each dog was then trotted on a level, straight surface at a pace of approximately 1.5 to 2m/s, past the camera which was mounted at the height of each dog's hip. Three passes were made past the camera to both sides with each dog. Freeze frames of each videoclip were taken at the end of the caudal stride phase, and the angle between the axes measured for each image. From ten (10) dogs twenty (20) hip extension measurements were

obtained. Once all twenty measurements had been recorded, the same procedure was repeated by a second assessor on the same twenty videoclips, but in random order. The second assessor was blinded to the results of the first assessor.

Each of the ten dogs then had passive hip extension angle measured on each of their hind limbs separately, using a goniometer. The dog was positioned in lateral recumbency. The fixed arm of the goniometer was placed along the pelvic axis, and the movable arm was placed along the femoral axis. Stabilising the pelvis, the femur was drawn caudally until passive resistance is felt, or the dog exhibited pain. The angle between the pelvic axis and the femoral axis, marked as in 3.3.3, was then noted. The same procedure was repeated on the contralateral hip with the dog lying on its other side. The process was repeated immediately by a second assessor using the same goniometer. The researcher and the second assessor were blinded to each other's measurements while the data collection was in progress.

3.4.5 Data analysis

There were now two paired sets of twenty data points consisting of two separate videographic hip extension measurements for each limb, as well as two separate goniometric hip extension measurements for each limb. A one-way analysis of variance was then performed on each of these two data sets to determine the correlation between the groups.

3.5 Normal group

3.5.1 Study design

A prospective, cross-sectional study.

3.5.2 Subjects

3.5.2.1 Number of dogs

A study by Jaegger et al (2002), using 16 healthy Labrador retrievers, determined that full passive hip extension in normal dogs is 162° with a standard deviation of 2. Assuming that normal weight-bearing hip extension range is 90% of full range, this becomes 145.8° , still with a standard deviation of 2. If a difference in the study population of 5° was considered significant, then at a confidence interval of 99%, the number of dogs in the sample would have been 13. However, 30 dogs were included into the sample used to determine normal values, based on the convention that normality can be assumed when $n=30$ or more.

3.5.2.2 Inclusion criteria

The same inclusion criteria were used in this part of the study as in section 3.3.2.2.

3.5.2.3 Exclusion criteria

The exclusion criteria in this part of the study were the same as for section 3.3.2.3.

3.5.3 Measurements

3.5.3.1 Videographic

The measurements for obtaining the videographic data for this part of the study were the same as in section 3.3.3.

3.5.3.2 Goniometric

The measurements for obtaining the goniometric data for this part of the study were the same as in section 3.4.3.2.

3.5.4 Procedure

The procedures for acquiring the data for this part of the study were the same as for section 3.4.4.

3.5.5 Data analysis

The mean for the two angles measured in each dog (left and right pelvic limb) was determined. These means (n=30) were grouped together in a single set of data for each measurement type, namely videographic and goniometric. An independent two-way t-test was performed on each data set, and the mean for the sample was obtained. In addition, the standard deviation (SD), confidence interval (CI) and p-value, set at 0.05, were determined.

The data collected were grouped into measurements for the left and the right limbs (30 values in each group). An independent t-test was then performed to determine if there was any difference between the means for the left and right limbs. This was done for each of the measurements, namely videographic and goniometric. P-values were also calculated for each test to determine the possibility that any results obtained from the t-tests were due to chance alone.

3.6 *Cranial Cruciate Ligament Disease Group*

3.6.1 Study design

This study was a prospective, two-part cross-sectional study of 16 dogs.

3.6.2 Subjects

3.6.2.1 Number of dogs

In determining the sample size for the CCL group, the anticipated results for the videographic part of the study was the deciding factor, as the hip extension *during gait* was the central question of this study. A sample size of at least sixteen (16) in each group to be compared had power in excess of 90% to detect a clinically significant difference in means of 10 degrees compared to the normal group. This was calculated based on the average standard deviation of 7.66 as determined in the normal group, and with a 0.05 one-sided level of significance.

3.6.2.2 Inclusion criteria

This study restricted its attention to adult working and gundog group dogs weighing between 20 to 35kg, and a body condition score of 2 to 4, including German Shepherds, Labrador Retrievers, Golden Retrievers and Pointers, presented at three different referral veterinary clinics in Johannesburg, and diagnosed with cranial cruciate ligament insufficiency.

3.6.2.3 Exclusion criteria

Exclusion criteria were any evidence of any other musculoskeletal pathology in the pelvic limb or lumbar spine, such as hip dysplasia, lumbosacral disc disease or spondylosis of the spine.

3.6.3 Measurements

3.6.3.1 Videographic

The measurements for obtaining the videographic data for this part of the study were the same as in section 3.3.3.

3.6.3.2 Goniometric

The measurements for obtaining the goniometric data for this part of the study were the same as in section 3.4.3.2.

3.6.4 Procedure

The procedures for acquiring the data for this part of the study were the same as for section 3.4.4.

3.6.5 Data analysis

The data sets collected in this section of the study can be grouped as follows:

- Videographic data
 - Maximum hip extension range of the unaffected hind limb during the stance phase of gait
 - Maximum hip extension range of the affected (CCL deficient) hind limb during the stance phase of gait
- Goniometric data
 - Maximum passive hip extension range of the unaffected hindlimb
 - Maximum passive hip extension range of the affected (CCL deficient) hind limb

The mean values of each of these data sets were then determined. The two sets of videographic data (affected and unaffected limbs) were then compared to the normal mean of the videographic data as calculated in 3.4 above, using an independent t-test to determine a p-value, set at 0.05. In the same way, the two sets of goniometric data (affected and unaffected limbs) were compared to the normal mean of the goniometric data. This was done to determine what differences, if any, existed between these data sets.

4.1 *Introduction:*

This chapter will describe four sets of results. Firstly, intra-rater as well as inter-rater reliability data will be analysed. The data collected for the normal group of dogs will then be outlined, with the relevant statistical analyses. This will illustrate the baseline data which was used later for comparison purposes with the cranial cruciate ligament (CCL) group. The data collected for the CCL deficient group and their statistical analyses will then be shown. Comparative data for the two groups will also be given.

4.2 *Intra-rater reliability*

The two sets of videographic measurements obtained from the random sample of ten (10) dogs were compared using a one-way analysis of variance, and were found to have a high correlation of $R = 0.96$ at a 95% confidence interval.

4.3 *Inter-rater reliability***4.3.1 *Goniometric measurements***

Two sets of data obtained from each of the ten (10) dogs in this pilot study – one data set from the researcher, and one data set from the second assessor. These two data sets were compared using a one-way analysis of variance, and found to have a high correlation of 0.92 at a 95% confidence interval.

4.3.2 *Videographic measurements*

Ten (10) dogs were used to test inter-rater reliability on the videographic measurements between two assessors. The values of the second assessor were compared to the values of

the first assessor using a one-way analysis of variance. A correlation of 0.97 was found between the two data sets, at a 95% confidence interval.

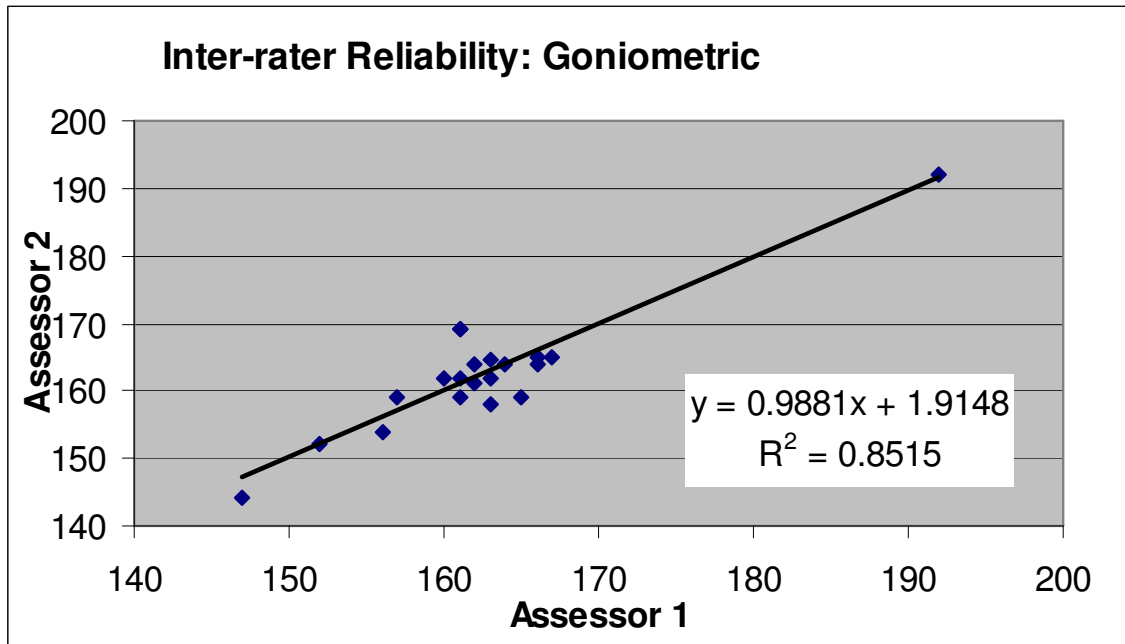


Figure 4.1: Inter-rater correlation: goniometric

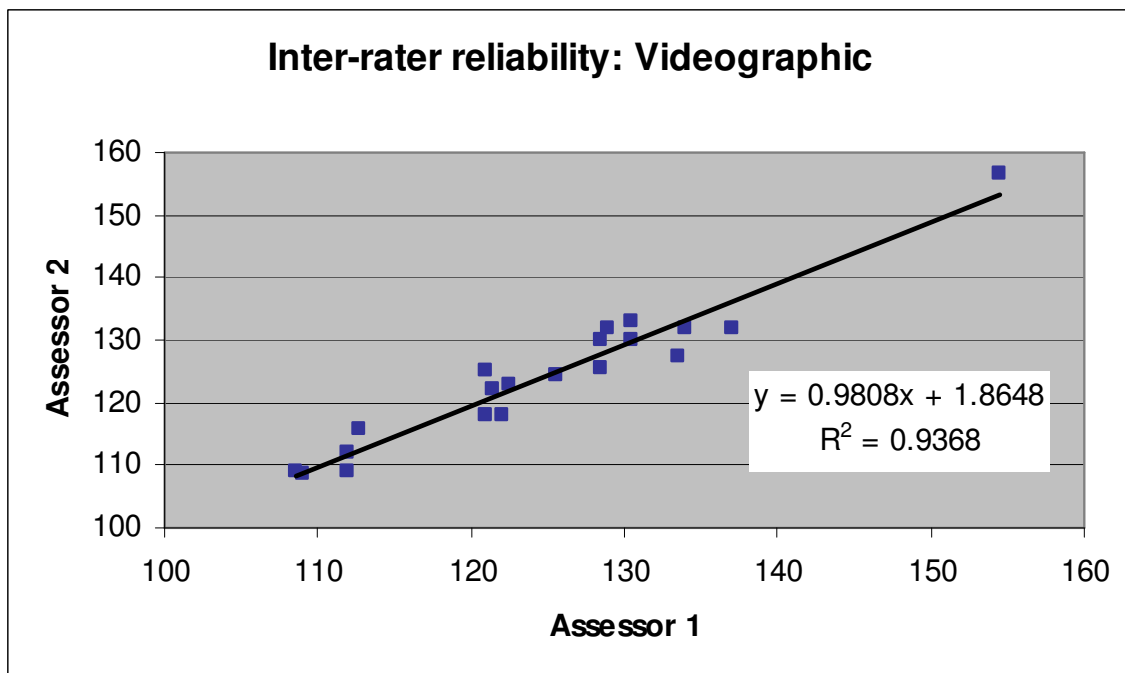


Figure 4.2: Inter-rater correlation: videographic

4.4 Normal Group

As stated previously, data on normal hip extension values during canine gait is not available in the literature. It was therefore necessary to conduct a pilot study to determine what the normal caudal excursion of the hip joint of the dog is during the stance phase of the gait cycle. Videographic and goniometric measurements of hip extension were taken of both hind limbs of each dog. These are illustrated in Table 4.1

Table 4.1 Results Normal Group

Measurements given in *degrees* (°)

	Normal(Left) +/-SD (CI=95%) (50%)	Normal (Right) +/-SD (CI=95%) (50%)	Mean +/-SD (CI=95%) (50%)	Diff +/-SD (CI=95%) (p-value)
Video	118.62 (+/- 9.42) (115.11-122.14) (118.67)	119.54 (+/- 12.42) (114.90-124.18) (117.67)	119.08 (+/- 8.5) (116.04-122.12) (118.5)	-0.92 (+/-14.03) (-6.16-4.32) (p = 0.72)
Goniometric	162.77 (+/- 3.84) (161.4-164.14) (163)	162.12 (+/- 4.07) (160.66-163.58) (163)	162.44 (+/- 3.73) (161.11-163.77) (163.25)	0.65 (+/-2.67) (-0.35-1.65) (p = 0.19)

It can be seen from the results that the mean degree of hip extension required for normal gait in this population as assessed videographically is approximately 119 degrees. A comparison of the videographic data for the left and the right limbs showed no significant difference in means. There was also no significant difference in means of passive maximum hip extension range between the left and the right hind limbs, as measured goniometrically. This means that the active hip extension required for normal gait is significantly less than the average maximum passive hip extension. These results provided a baseline for comparison for the data from the group of dogs suffering from cranial cruciate ligament deficiency.

4.5 Cranial Cruciate Ligament Group

Over a period of 12 months, the required sample of sixteen (16) dogs was found that met the inclusion criteria. The results can be seen in table 4.2.

Table 4.2: Results CCL Group

Measurements given in *degrees* (°)

		Affected leg +/-SD (CI=95%) (50%)	Unaffected leg +/-SD (CI=95%) (50%)	Mean difference +/-SD (p-value)
Video		115.87 (+/- 9.17) (111.32-120.42) (103.45)	126.12 (+/- 9.17) (121.24-131.01) (115)	10.26(+/-8.41) (4.52-13.66) (p<0.001)

A significant difference of 10.26 degrees was found between the means of the videographic measurements of the affected and the unaffected hind limbs. A comparison of the goniometrically measured means of the two hind limbs showed an even greater difference of 14.22 degrees. Therefore both active and passive hip extension range was significantly reduced in the affected hind limb when compared to the unaffected hind limb. It can also be seen that the distribution of the data was skewed to the left, indicating that the trend was towards a smaller angle of hip extension range as measured in the data.

4.6 Normal group vs. CCL group

The comparison of all the measurements can be seen in table 4.3.

Table 4.3: Combined Results Normal and CCL Groups

Measurements given in *degrees* (°)

	Normal mean +/-SD (CI=95%) (50%)	Affected leg +/-SD (CI=95%) (50%)	Unaffected leg +/-SD (CI=95%) (50%)
Video	119.08 (+/- 8.5) (116.04- 122.12) (118.5)	115.87 (+/- 9.17) (111.32-120.42) (103.45)	126.12 (+/- 9.17) (121.24-131.01) (115)
Goniometric	162.44 (+/- 3.73) (161.11-163.77) (163.25)	143.81 (+/- 7.57) (139.78-147.85) (102.69)	158.03 (+/- 7.30) (154.14-161.92) (107.75)

When compared to the normal mean, the mean active (videographic) hip extension range of the unaffected limb was slightly greater than normal, and the mean active hip extension range of the affected limb was slightly lower than normal. However, neither of these mean values differed significantly from the normal mean.

The passive hip extension range of both the unaffected and the affected limbs were significantly reduced compared to the normal mean, but the hip extension range of affected limb was reduced four times more than the reduction in range of the unaffected limb.

4.7 Conclusion

Six sets of data were compared and are presented in the following summary. The first three sets of data were videographic, and the second three sets were goniometric measurements. The data sets that had results that were statistically significant at a 95% confidence interval are illustrated in Table 4.4, as well as in Figure 4.3.

Table 4.4 Summary of data analyses

DATA SET	DIFFERENCE (reduction)	P-VALUE
Normal videographic vs normal goniometric	43.36	<0.001
Normal goniometric vs. unaffected goniometric	4.41	<0.001
Normal goniometric vs. affected goniometric	18.63	<0.001
Normal videographic vs. affected goniometric	24.73	<0.001
Affected goniometric vs. unaffected goniometric	14.18	<0.001
Normal videographic vs. unaffected videographic	-7.04	0.007
Normal videographic vs. affected videographic	3.21	0.12
Affected videographic vs.unaffected videographic	10.26	<0.001

As anticipated, there was no significant difference between the hip extension measurement, either videographic or goniometric, of the left and right hind limbs of the normal group of dogs. On review of the goniometric data, it has been shown that the maximum passive hip extension range in dogs with CCL insufficiency is significantly reduced in both hind limbs. However, the reduction in hip extension range of the affected hind limb was significantly greater than was seen in the unaffected hind limb. During gait, the videographic data showed that there was a significant reduction in the mean hip extension range of the affected hind limb compared to the unaffected hind limb of the CCL group of dogs. This difference in hip extension range reflected the difference in passive hip extension range as determined goniometrically. Therefore, not only was passive, non-weight-bearing hip extension range in the CCL deficient group of dogs significantly reduced when compared to normal values, there was also a significant reduction in both passive and active hip extension range of the affected hind limb compared to the unaffected hind limb, showing a direct link between CCL insufficiency and loss of hip extension range at the ipsilateral hip joint.

5.1 Introduction

In this discussion, the data collected from the normal group of dogs and the results obtained from analysis of these data will be discussed first. Then the data analysis obtained from the CCL group and the implications of these results will be discussed. The results from the normal and the CCL groups will then be compared.

This study started off with a hypothesis that dogs that suffer from a chronic cranial cruciate ligament insufficiency may also develop a concurrent reduction in hip extension range. This hypothesis was based on the researcher's observations in clinical practice. The aims of the study were therefore to determine whether there is in fact an associated decrease in hip extension range in dogs with CCL insufficiency. However, such a reduction in range would only be significant if it was large enough to affect gait. While maximum hip extension in Labrador Retrievers has been determined (Jaegger et al 2002), full maximum hip extension range is not required for gait at low speed. Since no data on hip extension range during gait could be found in the literature, this also needed to be determined in this study.

5.2 The normal group

The first consequence of these results was that the results of the study by Jaegger et al (2002) could be corroborated. The mean passive hip extension range determined in their study was 162° (± 3), while the results of the data collected from the normal group in this study showed a mean of 162.44° (± 3.73). The population sampled in this study was less homogenous than the population sampled in the Jaegger et al study, as it sampled dogs from different breeds, albeit from the same classification category. It can therefore be shown that adult dogs that are of a morphological type similar to those classified as

working or gundogs by the FCI (Federation Cynologique Internationale), can be expected to have a range of passive hip extension that does not vary more than 4 degrees from 162 degrees.

The second result obtained from the data collected was the range of hip extension required for normal canine gait at a speed of 1.5 – 2 m/s. This showed that there is a significant difference of 43.36 degrees between maximum passive hip extension and maximum hip extension during the stance phase of gait. This means that a reduction in passive hip extension of less than 43 degrees may not necessarily affect functional gait patterns. The standard deviation from this figure is significantly higher than the when passive hip extension range was measured. There were three variables that were difficult to control for, and are the most likely explanations for this high standard deviation. These three factors are:

- a) **Variability in walking speed:** The dog handlers were asked to walk their dogs at a brisk pace past the camera. However, there were possibly differences in the speed at which the dogs were walked.
- b) **Variability in camera angle:** The handlers were given a line to walk their dogs along, which was at a set distance from the camera (1m). This is a practical and clinically useful assessment technique, but one must be aware that the dogs will not always keep precisely to the given line, and this may result in small variations in angle of the hind limb to the camera, which in turn has an affect on the angle measured.
- c) **Variability in the dog's attitude and training:** All dogs used in this study had basic training and could walk at heel on a lead. However, environmental distractions and degree of obedience had an effect on the dog's desire to go forward in a straight line. It is the opinion of the researcher that this factor can not be controlled for.

Nevertheless, this provided a baseline for comparison of the data compiled from the sample of CCL deficient dogs, and has contributed to the understanding of normal canine gait.

5.3 The CCL group

The goniometric data for the CCL group showed that the passive hip extension range of the affected hind limb was 14.18 degrees ($p < 0.001$) less than that of the unaffected limb. This indicates that there is a direct correlation between CCL deficiency and a significant reduction in passive hip extension range in the ipsilateral hind limb. In this study sample none of the dogs included had any other pathological processes affecting the musculoskeletal system. Therefore, the reduction in hip extension range shown could only be a direct consequence of dysfunction at the stifle joint. The only structures that directly link the stifle and the hip joints are the two-joint muscles of the stifle. In the acute stages of CCL rupture, the dog presents with hyperflexion of both the stifle and the hip joint. The sartorius muscle is a two-joint muscle that flexes both the stifle and the hip. Overuse of this muscle could result in shortening of the muscle, resulting in a reduction in range. The gait alteration observed in dogs presenting with chronic CCL insufficiency is more likely to lead to changes in soft tissue characteristics such as muscle sarcomere length and extensibility of fascia, tendons and ligaments. The stifle hyperextension seen in chronic CCL pathology and associated compensatory increase in hip flexion angle implicates the following two muscles: rectus femoris and tensor fascia latae. Both of these muscles are two-joint muscles of the stifle and hip joint. Their actions are extension of the stifle with simultaneous flexion of the hip joint. If the hip joint is sustained within a limited range for an extended period of time, internal fibre disorganisation of, as well as water and proteoglycan loss from the ligaments and tendons around the hip will cause restricted range of motion of the joint (Norkin & Levangie 1992).

When the videographic data was analysed, it was shown that the CCL deficient hind limb had significantly reduced hip extension range of 10 degrees during gait compared to the

unaffected hind limb. This observation provides a practical and clinically applicable measurable parameter for the observable gait alteration or ‘lameness’ seen in dogs with CCL insufficiency.

5.4 Normal group vs. CCL group

The data of the CCL group were then compared to the values determined for the normal group. The results of these analyses were required to answer the research question posed at the beginning of the study, which is whether dogs with CCL deficient stifles have an associated decrease in hip extensor range that is large enough to affect normal trotting gait.

An analysis of the goniometric data showed that the hip extension range values of both hind limbs of the CCL group dogs were significantly reduced compared to the normal mean, but much more so in the affected limb than the unaffected limb. However, even though the hip extension range of affected limb was reduced by almost 19 degrees, the mean passive hip extension range of the affected limb did not equal the mean normal hip extension range measured during gait. This finding appears to support the hypothesis that full passive hip extension range is not required for normal gait at low speeds. However, when comparing the videographic data of the normal group to the affected group, interesting differences in hip extension range were in fact found. The mean hip extension range of the affected hind limb was only slightly reduced compared to the normal mean, correlating with the results of Madore et al (2007), who showed that the caudal stance phase is not severely affected in cases of stifle degeneration. The major difference in the videographic data was the difference between the normal mean and the unaffected limb. The mean hip extension range of the unaffected limb was significantly higher than the normal mean. This significant difference was not anticipated at the start of this study, and is most likely due to increased loading of the unaffected limb to compensate for pain in the CCL deficient limb. In the clinical setting it is therefore important to recognise this

factor, and take steps to minimise strain on the contralateral hind limb by increasing the strength and stability of this limb.

5.5 Clinical relevance

This study succeeded in showing that there is a statistically significant reduction in passive hip extension range associated with CCL insufficiency in dogs. It has also been shown that dogs with CCL insufficiency exhibit a significant difference in hip extension range between the affected and the unaffected hind limb during gait, with the range of the unaffected hind limb being greater than the affected limb. In the clinical scenario, these two measured differences could be used as an early red flag for the insidious development of cruciate insufficiency and stifle pain. Current concepts in the treatment and rehabilitation of the canine CCL do not include much consideration for the effect that CCL deficiency has on both the ipsilateral and the contralateral hip joint. This study highlights the need for the clinicians involved in both the primary treatment as well as the rehabilitation of CCL deficient dogs to consider and assess the hip joints as part of their therapeutic approach. This would require a thorough evaluation of both the accessory motions of the coxofemoral joint as well as the flexibility of the surrounding soft tissues. Treatment should be aimed at restoring full range of motion at the hip joint and strengthening the muscles around the joint.

5.6 Recommendations for further research

This study has added to the body of knowledge regarding canine gait by showing the hip extension range required for normal gait. The strong relationship between CCL pathology and hip dysfunction also demonstrates the need for research into the implementation and efficacy of treatment and rehabilitation protocols to prevent and address restricted hip extension range in dogs diagnosed with CCL problems.

6.1 Main findings

In this chapter, the main findings of this study are summarized:

- There was good intra-rater reliability of the videographic measurements used to collect the data for this study.
- The inter-rater reliability for both the goniometric and videographic measurements used to collect data for this study was good.
- There was a difference in mean maximum hip extension range between passive hip extension and weight-bearing hip extension during gait of about 43 degrees.
- There was a significant difference in both maximum passive hip extension range and maximum weight bearing hip extension range during gait between the affected and the unaffected hind limbs of dogs with CCL insufficiency.
- There was a reduction in maximum passive hip extension range of the hind limbs of the CCL deficient dogs, which was greater for the affected hind limb than for the unaffected hind limb. The videographic data showed some reduction in maximum weight bearing hip extension range during gait between the affected hind limbs of dogs with CCL insufficiency and the normal mean. The data also showed a significant increase in hip extension range during gait for the unaffected limb compared to the normal mean.

6.2 Summary

The results of this study support the hypothesis that in dogs with CCL insufficiency, there is a reduction in passive hip extension range. During gait, the data has shown a significant difference in maximum hip extension between the

two hind limbs of the CCL deficient dog, with the unaffected hind limb exhibiting an increased extension angle. These factors should be taken into consideration in the treatment and rehabilitation of dogs with CCL insufficiency.

CHAPTER 7 REFERENCES

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APPENDIX A

Body condition score chart (Hill's)

	5 - Obese	
	The ribs are very difficult to feel under a thick fat cover. The tailbase* appears thickened and is difficult to feel under a prominent layer of fat. The bony prominences are covered by a moderate to thick layer of fat. In animals over six months, there is a pendulous ventral bulge and no waist when viewed from the side. The back is markedly broadened when viewed from above. Marked abdominal fat apron present in cats.	
	4 - Overweight	
	The ribs are difficult to feel with moderate fat cover. The tailbase* has some thickening with moderate amounts of tissue between the skin and bone. The bony structure can still be felt. The bony prominences are covered by a moderate layer of fat in animals over six months, there is little or no abdominal tuck or waist when viewed from the side and the back is slightly broadened when viewed from above. Abdominal fat apron is present in cats.	
	3 - Ideal	
	The ribs are easily palpable with a slight fat cover. The tailbase* has smooth contour or some thickening and the bony structures are palpable under a thin layer of fat between the skin and bone. The bony prominences are easily felt with a slight amount of overlying fat. In animals over six months, there is an abdominal tuck when viewed from the side and a well proportioned lumbar waist when viewed from above.	
	2 - Underweight	
	The ribs are easily palpable with minimal fat cover. The tailbase* has a raised bony structure with little tissue between the skin and bone. The bony prominences are easily felt with minimal overlying fat. In animals over six months, there is an abdominal tuck when viewed from the side and a marked hourglass shape when viewed from above.	
	1 - Very Thin	
	The ribs are easily palpable with no fat cover. The tailbase* has a prominent raised bony structure with no tissue between the skin and bone. The bone prominences are easily felt with no overlying fat. In animals over six months, there is severe abdominal tuck when viewed from the side and an accentuated hourglass shape when viewed from above.	

APPENDIX B

University of the Witwatersrand ethical clearance form

AESC 3

STRICTLY CONFIDENTIAL

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

ANIMAL ETHICS SCREENING COMMITTEE

CLEARANCE CERTIFICATE NO:

2006

30

2A

APPLICANT: A.M. van der Walt

DEPARTMENT: Physiotherapy

PROJECT TITLE: Reduction in hip extension range in dogs with chronic cranial cruciate ligament insufficiency

Species	Number	Expiry Date
Dog	100	May 2008

- i) Approval is hereby given for the experiment described in the above application.

The use of these animals is subject to AESC Guidelines for the use and care of animals, is limited to the procedures specified in the application form, and to:

APPROVED: subject to changing the wording on the Consent Form from "will not experience any discomfort" to "will experience minimal discomfort" (9th line from bottom, first page)

SIGNED



Chairman: Animal Ethics Screening Committee

DATE: 24th April 2006

- ii) I am satisfied that the persons listed in this application are competent to perform the procedures therein, in terms of Section 23(1)(c) of the Veterinary and Para-veterinary Professions Act (19 of 1982)

SIGNED



Registered Veterinarian

DATE: 24th April 2006

APPENDIX C

Informed consent form: normal group

INFORMED CONSENT FORM: NORMAL GROUP

TITLE OF STUDY:

**REDUCTION IN HIP EXTENSION RANGE IN DOGS
WITH CHRONIC CRANIAL CRUCIATE LIGAMENT
INSUFFICIENCY**

RESEARCHER:

AM van der Walt BPhysT (UP)

SUPERVISORS:

**Prof AV Stewart
Dr KE Joubert**

**In fulfillment of the degree MSc by dissertation at the University of the Witwatersrand,
faculty of Medicine, Department of Physiotherapy.**

Aims and purpose of the research:

This study consists of two parts. The first part of the study aims to determine what the range of hip extension is in normal dogs, and what percentage of this normal range is required for normal gait. The second part of the study will determine how hip extension range in dogs with cranial ligament strain differs from normal dogs, both in terms of maximum hip extension and hip extension range used during gait.

Why we need your dog:

Your dog has been randomly selected from a group of healthy working dogs between the ages of 3 and 7. We need your dog to determine what normal hip extension range is. To enable us to do this we need to do the following:

- Ask you a few questions about your dog's history to make sure your dog is the right candidate for the study.
- Place stick-on markers on your dog and then take videoclips of your dog walking three times in each direction
- Measure your dogs range of hip extension on each side
- Take an x-ray of each of your dog's hips in extension. Your dog will not be sedated or drugged in any way to do this.

We are confident that your dog will not experience any discomfort or health risks by participating in this study.

While neither you nor your dog stand to benefit directly by participating in this study, we are confident that the information gained will benefit many dogs suffering from this very common condition in the future.

Should you require more information, we would be more than happy to provide you with it, either verbally or in writing.

You will be free to withdraw your dog from the study at any time with no prejudice, and will not need to give any reasons for your withdrawal.

Contact details: Ansie van der Walt
083 251 8457

CONSENT FORM: NORMAL GROUP

TITLE OF STUDY:

**REDUCTION IN HIP EXTENSION RANGE IN DOGS
WITH CHRONIC CRANIAL CRUCIATE LIGAMENT
INSUFFICIENCY**

RESEARCHER:

AM van der Walt BPhysT (UP)

SUPERVISORS:

**Prof AV Stewart
Dr KE Joubert**

**In fulfillment of the degree MSc by dissertation at the University of the Witwatersrand,
faculty of Medicine, Department of Physiotherapy.**

1. I have read the accompanying information sheet, and understand the purpose and nature of the study I have been asked to allow my dog to participate in.

Signed _____

2. I have had the opportunity to ask questions regarding the study, and any questions have been answered to my satisfaction.

Signed _____

3. I am satisfied that I have received enough information regarding the nature and purpose of the study

Signed _____

4. I hereby give permission for my dog to be included as a participant in the abovementioned study.

Signed on the _____ day of _____ (month) 2006

at _____ (place)

_____ (print name)

_____ (signature)

Owner

_____ AM van der Walt

APPENDIX D

Informed consent form: CCL group

INFORMED CONSENT FORM: CRANIAL CRUCIATE LIGAMENT GROUP

TITLE OF STUDY:

**REDUCTION IN HIP EXTENSION RANGE IN DOGS
WITH CHRONIC CRANIAL CRUCIATE LIGAMENT
INSUFFICIENCY**

RESEARCHER:

AM van der Walt BPhysT (UP)

SUPERVISORS:

Prof AV Stewart

Dr KE Joubert

**In fulfillment of the degree MSc by dissertation at the University of the Witwatersrand,
faculty of Medicine, Department of Physiotherapy.**

Aims and purpose of the research:

This study consists of two parts. The first part of the study aims to determine what the range of hip extension is in normal dogs, and what percentage of this normal range is required for normal gait. The second part of the study will determine how hip extension range in dogs with cranial ligament strain differs from normal dogs, both in terms of maximum hip extension and hip extension range used during gait.

Why we need your dog:

Your dog has been randomly selected from a group of working dogs between the ages of 3 and 7 that have an injury to the cranial cruciate ligament. We need your dog to determine whether hip extension range is reduced in dogs suffering from cranial cruciate ligament disease. To enable us to do this we need to do the following:

- Ask you a few questions about your dog's history to make sure your dog is the right candidate for the study.
- Place stick-on markers on your dog and then take videoclips of your dog walking three times in each direction
- Measure your dogs range of hip extension on each side
- Take an x-ray of each of your dog's hips in extension. Your dog will not be sedated or drugged in any way to do this.

We are confident that your dog will not experience any discomfort or health risks by participating in this study.

While neither you nor your dog stand to benefit directly by participating in this study, we are confident that the information gained will benefit many dogs suffering from this very common condition in the future.

Should you require more information, we would be more than happy to provide you with it, either verbally or in writing.

You will be free to withdraw your dog from the study at any time with no prejudice, and will not need to give any reasons for your withdrawal.

Contact details: Ansie van der Walt
083 251 8457

CONSENT FORM: CRANIAL CRUCIATE LIGAMENT GROUP

TITLE OF STUDY:

**REDUCTION IN HIP EXTENSION RANGE IN DOGS
WITH CHRONIC CRANIAL CRUCIATE LIGAMENT
INSUFFICIENCY**

RESEARCHER:

AM van der Walt BPhysT (UP)

SUPERVISORS:

Prof AV Stewart

Dr KE Joubert

**In fulfillment of the degree MSc by dissertation at the University of the
Witwatersrand, faculty of Medicine, Department of Physiotherapy.**

5. I have read the accompanying information sheet, and understand the purpose and nature of the study I have been asked to allow my dog to participate in.

Signed _____

6. I have had the opportunity to ask questions regarding the study, and any questions have been answered to my satisfaction.

Signed _____

7. I am satisfied that I have received enough information regarding the nature and purpose of the study

Signed _____

8. I hereby give permission for my dog to be included as a participant in the abovementioned study.

Signed on the _____ day of _____ (month) 2006

at _____ (place)

_____(print name)

_____(signature)

Owner

AM van der Walt