# ผลทางคลินิกของการใช้ถุงเท้ากันลื่นในสุนัขพันธุ์ปอมเมอเรเนียน ที่ได้รับการผ่าตัดแก้ไขสะบ้าเคลื่อนเข้าด้านใน

นางสาววิภา เต็มคุณธรรม



วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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CLINICAL OUTCOMES OF NON-SLIPPING SOCKS APPLICATION IN POMERANIANS UNDERGOING SURGICAL CORRECTION OF MEDIAL PATELLAR LUXATION

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A Thesis Submitted in Partial Fulfillment of the Requirements
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วัตถุประสงค์ของงานวิจัย เป็นการศึกษาผลของถุงเท้ากันลื่นต่อพิสัยข้อต่อในสุนัขพันธุ์ปอมเมอเรเรียนที่ได้รับการผ่าตัดแก้ไขสะบ้าหัวเข่าเคลื่อนเข้าด้านในระดับที่ 3 โดยการศึกษาแบ่งสุนัขออกเป็นสองกลุ่ม กลุ่มที่ 1 เป็นสุนัขที่ออกกำลังกายโดยไม่ใช้ถุงเท้า (control group) 10 ตัว กลุ่มที่ 2 กลุ่มการทดลอง เป็นสุนัขที่ใส่ถุงเท้าในระหว่างการออกกำลังกาย (experimental group) 10 ตัว ในกลุ่มการทดลอง มีการเก็บข้อมูลในส่วนจลน์ศาสตร์การเคลื่อนไหว (kinematic data) ขณะที่ไม่ใส่ถุงเท้า (Experimental A group: Ex A) และขณะใส่ถุงเท้า (Experimental B group: Ex B) หลังการผ่าตัดสุนัขจะได้รับการออกกำลังกายโดยการวิ่งบนลู่วิ่งบก อาทิตย์ละ 3 ครั้ง ครั้งละ 10 นาที เป็นระยะ 2 เดือน โดยเริ่มออกกำลังกายในวันที่ 14 หลังการผ่าตัด มีการประเมินผลในส่วนของข้อมูลจลน์ศาสตร์การเคลื่อนไหว การวัดพิสัยข้อต่อโดยใช้เครื่องมือวัดมุม (goniometer) และการประเมินลักษณะการเดินกะเผลก (lameness score) โดยช่วงเวลาที่เก็บข้อมูลเพื่อวัดผลการศึกษาจะเก็บข้อมูลทั้งหมด 5 ครั้ง คือ ก่อนการผ่าตัด หลังการผ่าตัดสัปดาห์ที่ 2, 4, 6 และ 8 ผลการศึกษาพบว่า สุนัขในกลุ่มที่ใส่ถุงเท้าในการออกกำลังกาย มีผลต่อพิสัยข้อต่อในการยืด (maximum extension angle) ที่ดีขึ้นในสัปดาห์ที่ 4 และ 6 อย่างมีนัยสำคัญ (P-value < 0.05) และพบว่าขณะออกกำลังกายโดยการใส่ถุงเท้าสุนัขมีพิสัยข้อต่อ (Range of motion) ของข้อเข่ามากขึ้น และพิสัยข้อต่อขณะหด (maximum flexion angle) ของข้อเข่าน้อยลงในขณะวิ่งเมื่อเปรียบเทียบกับกลุ่มควบคุมในทุกสัปดาห์ โดยเฉพาะอย่างยิ่งในสัปดาห์ที่ 2 และ 4 พบความแตกต่างอย่างมีนัยสำคัญ (P-value < 0.05) ส่วนการวัดมุมข้อต่อโดยใช้เครื่องมือวัดมุมข้อต่อ และการประเมินลักษณะการเดินกะเผลก พบว่า ในกลุ่มการทดลองมีผลที่ดีขึ้น อย่างไรก็ตามไม่พบความแตกต่างจากกลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ กล่าวโดยสรุป การใส่ถุงเท้ากันลื่นขณะวิ่งสามารถใช้เพื่อเพิ่มประสิทธิภาพในการกายภาพบำบัดในสุนัขได้

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KEYWORDS: KINEMATIC GAIT ANALYSIS, MEDIAL PATELLAR LUXATION, POMERANIANS, RANGE OF MOTION

WIPA TEMKUNNATHAM: CLINICAL OUTCOMES OF NON-SLIPPING SOCKS APPLICATION IN POMERANIANS UNDERGOING SURGICAL CORRECTION OF MEDIAL PATELLAR LUXATION. ADVISOR: ASST. PROF. KUMPANART SOONTORNVIPART, D.V.M., Ph.D., D.T.B.V.S., CO-ADVISOR: ASST. PROF. CHALIKA WANGDEE, D.V.M., M.Sc., Ph.D., D.T.B.V.S., 57 pp.

The objectives of the study were to investigate the effects of non-slipping socks on active range of motion, passive range of motion and lameness scores in Pomeranians undergoing surgical correction of grade 3 medial patellar luxation. Dogs were divided into two groups; the control group (n=10 dogs), and the experimental group (n=10 dogs). In experimental group, the data were collected while non-wearing non-slipping socks (Experimental A group: Ex A) and while wearing non-slipping socks (Experimental B group: Ex B). Both groups were brought to walk and trot on treadmill for 10 minutes three times a week on treadmill. Starting at 14$^{th}$ day after surgical correction, non-slipping socks were applied in dogs in the experimental group during trotting on the treadmill. This scheduled activity was repeated every 2 weeks until 8 weeks. Clinical outcomes were assessed basing on range of motion (ROM), maximum extension angle (MEA), maximum flexion angle (MFA), passive range motion of the stifle joint using goniometer and lameness scores. These data were collected 5 times; prior to surgery, 2, 4, 6 and 8 weeks after surgery. The results showed that the MEA of stifle joint was significantly greater in the experimental group at 4 and 6 weeks post-operatively when compared with the control group. There were statistically significant increase ROM and decrease MFA of the stifle joints at 2 and 4 weeks post-operatively in wearing non-slipping socks when compared with the non wearing non-slipping socks . In conclusion, trotting combinated with wearing non-slipping socks could be used to gain effectiveness for veterinary physical therapy in dogs.

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| Department: | Veterinary Surgery | Student's Signature | ............................ |
| Field of Study: | Veterinary Surgery | Advisor's Signature | ............................ |
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# CHAPTER I
# INTRODUCTION

## Importance and Rationale

Medial patellar luxation (MPL) is the most common developmental orthopedic disorder in small breed dogs. In Thailand, a high incidence of patellar luxation is in Pomeranians, one of the most raised small breeds in the country (Soontornvipart et al., 2013). MPL that occurs over time can significantly contribute to secondary degenerative joint disease (DJD), pain and hind limb lameness (Hulse, 1981; Wangdee et al., 2013). The patellar luxation can be treated both conventionally and surgically, depending on clinical signs, physical examination and age of dogs. Conventional treatment is suitable for asymptomatic patients or old dogs while surgical option for critical signs of lameness and young dogs with growth plates still growing. The surgical treatment aims to improve extensor mechanism realignment of the knees as well as reposition and stabilize the patellar in the femoral trochlear groove (Wangdee et al., 2013). The surgical treatment of patellar luxation is a combination of soft tissue and bone reconstructions. The important techniques of soft tissue reconstruction include desmotomy, retinaculum and fascia overlap or imbrication, anti-rotational suture and quadriceps release. Bone reconstruction applied to correct skeletal deformity (internal rotation of the tibial crest and shallow of femoral groove) are trochleoplasty and transposition of the tibial tuberosity (L'Eplattenier, 2002). Correction of angular limb deformities is also necessary in the most severe cases (Linney et al., 2011). However surgical procedures can lead to restricted range of motion (ROM) because open wounds over joints allowed to heal secondarily by contraction and epithelialization may result in limitations passive range of motion (PROM). Surgical incisions may result in adhesions and fibrosis between skin, subcutaneous tissues, fascia, muscles and bone, limited the ability of tissues to glide over one another. Musculotendinous tissue may also be relatively shortened as a result of spasm or contracture. Any restriction of motion may result in resistance to joint movement and pain (Millis and Levine, 2014)

Joint immobilization may have adverse effects on articular structure as well as muscle, bone, tendons and ligament (Marsolais et al., 2003). Therefore, physical therapy to increase ROM is important in dogs after surgery. ROM exercises are ideal for diminishing the effects of disuse and immobilization of the joint. To maintain ROM, the joints and muscles must be moved through their available ranges. When joint motion restriction is present, activities to encourage a more complete ROM is necessary. ROM exercise is divided into two parts: AROM exercise and PROM exercise. PROM performed by the therapist using the external force, helps prevent contracture of periarticular tissues and improves synovial fluid production and diffusion. In AROM performed by dogs during a regular gait cycle, increases active muscle contraction and strength which PROM does not have this advantage. The activities that may be performed include walking in snow, in sand, in tall grass and swim.

There are several studies to assess activity which can enhance AROM in dogs. Holler et al. (2010) studied kinematic joint of the forelimb and hind limb during walking on incline slope, decline slope and over low obstacle (cavaletti) compared with walking on horizontal surface. The results indicated that walking on incline surface and low obstacle was a specific physical therapy for dogs. Kinematic analysis of AROM was conducted previously in various activities such as stair climbing and swimming. The AROM of forelimbs and pelvic limbs are investigated during ascending the stair compared with trotting on ground surface. The study found that walking on ramp or ascending stair provided increase in range of motion of forelimbs and pelvic limbs (Millard et al., 2010; Durant et al., 2011; Carr et al., 2013). Swimming provided greater range of motion of the stifle and hip joints compared with walking in dogs undergone surgical correction of cranial cruciate ligament rupture (Marsolais et al., 2003).

Currently, in clinical practice, there are more use of non-slipping socks in dogs because it prevents slipping of in a house with slippery floor. In human, non-slipping socks have been used widely in older people to prevent falling because the non-slipping socks provide greater traction on slippery surfaces (Hatton et al., 2013). From clinical observation, wearing non-slipping socks helps the dog increase movement of joint. The principle is similar to other exercise ways on increasing the AROM such as walking in tall grass, sand, snow, etc. Moreover, AROM exercise enhances muscle strengthening and endurance together with more flexion of joint as a result of increased ROM.

The aims of this study were to investigate the effects of non-slipping socks on active range of motion, passive range of motion and lameness scores in Pomeranians undergoing surgical correction of medial patellar luxation. Two-dimensional kinematic analysis was used for evaluating the AROM.

We hypothesized that AROM of pelvic limbs of dog would be greater than that of wearing non-slipping socks compare with the control group. In addition, Pomeranians wearing non-slipping socks will have better ROM, PROM and lameness scores when compared with those of the control group.

## CHAPTER II
## LITERATURE REVIEW

### 2.1 Medial patellar luxation

#### 2.1.1 General introduction

Medial patellar luxation (MPL) is one of the most common orthopedic conditions in small-breed animals. In Thailand, the prevalence of MPL in miniature and toy dogs is 87% (Soontornvipart et al., 2013). Small breeds of dogs are 12 times more likely to develop MPL than larger breeds. Breed predilections have been reported in Boston Terrier, Chihuahua, Pomeranian, Miniature Poodle, and Yorkshire Terrier (Campbell and Horstman, 2011). Dogs with MPL have diminished strength of the extensor muscles of the stifle joint and additional stress on weight-bearing joints that can lead to secondary DJD, pain and hind limb lameness (Hulse, 1981; Wangdee et al., 2013). Definitive causes for MPL have not been elucidated but the condition possibly inherited through genetics has been suggested (Roush, 1993; Soontornvipart et al., 2013). The severity of musculoskeletal changes depends on age of onset and duration of luxation (Roush, 1993). MPL in young animals causes unequal force between medial and lateral parts of distal femoral growth plate which develops angular and torsional abnormalities while MPL in aging animal results in DJD (Roush, 1993).



Mainly, medial luxation of the patellar is primarily a developmental disease whereas traumatic patellar luxation occurs less commonly (Campbell and Horstman, 2011). Occurring medial patellar luxation has a crucial impact on cranial cruciate ligament (CCL). MPL continuously increases stress on the CCL, which begins to tear, eventually causing joint structure degeneration and CCL rupture (Alam et al., 2011). In comparison, nearly all dogs with CCL disease have a higher MPL severity in the sniffle joint than the intact joint. Dogs with grade 4 MPL have higher predisposition for CCL rupture compared to dogs presented in other grades of MLP (Campbell and Horstman, 2011)

2.1.2 Anatomy of the stifles joint

Stifle joint is major complex condylar synovial joint, there are three joints consist of femorotibial, femoropatellar and proximal tibiofibular joints. Femorotibial is major articulate of the stifle joint and primary weight bearing articulation (Kowaleski et al., 2012) articulate between roller-like , thick condyle of femur and flatted condyle of tibia free form femoropatellar joint which located between patellar and trochlear groove of femur. There are two parts of meniscus located between tibia and femur. The joint capsule of stifle joint is largest of the body divided into three compartment, two of this located between tibia and femoral condyle on medial and lateral side.

The Patellar bone is the largest sesamoid bone in the body. It is ovate in shape and slightly curved to articulate with femoral trochlear groove. The patella is ossification in patella tendon, which insertion of the quadricep muscle group. Extensor mechanism composed of quadricep muscle, patellar, patellar ligament, tibial tuberosity, patellar retinaculum and adjacent soft tissue (Figure 1). Abnormal alignment of these structures result to abnormal mechanic and joint instability as a result of patellar luxation.

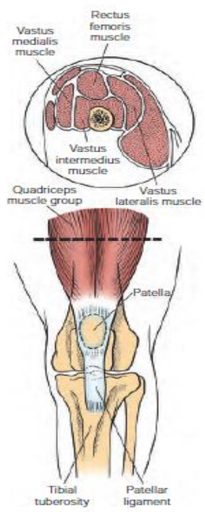


Figure 1 Anatomic diagram of normal soft tissue and skeletal structures associated with the quadriceps extensor mechanism (Schulz, 2013).

2.1.3 Diagnosis and grading

Grades of luxation associate with presenting degree of clinical signs and severity of pathological changes. According to Singleton's patellar luxation grading system, patellar luxation is classified from grade I to IV (Singleton, 1969).

Grade I: No clinical sign of hindlimb lameness. Patella is able to luxated at full extension of the stifle joint or manual push but return immediately in trochlear groove when release the pressure. There is no crepitus and is minimal internal rotation of tibia. No abduction of hock.

Grade II: Patellar luxation more frequent than grade I. There is tibia rotation up to 30° and tibial crest slightly deviation. While patella luxate medially the hock always abducts. In some case, patellar luxate on medial condyle of femur result of erosion of articular cartilage of patellar and proximal area of trochlear ridge and occur crepitation. Clinical sign is intermittent lameness associated when patella luxate out of the trochlear groove but nonpainful.

Grade III: The patella is luxate permanently but it's can return to trochlear groove when manually reduced. Lameness is related with degree of cartilage damage. Usually found "crouch" gait (abnormal pattern grade than inter). There is rotation and deviation of tibial crest at 30 to 60°. Bone deformity are often more severe compare with lower grade. Dog always uses limb in semi-flexion of stifle joint and abduction and adduction of hock while flex and extension of stifle joint.

Grade IV: luxation, patella luxation is permanent, non-reducible acute worsening of the chronic lameness and is often found concurrence rupture of cranial cruciate ligament. There is rotation of tibia and tibia crest deviation between 60° to 90 °. Diagnosis of patella luxation based on palpation of patella and stifle.

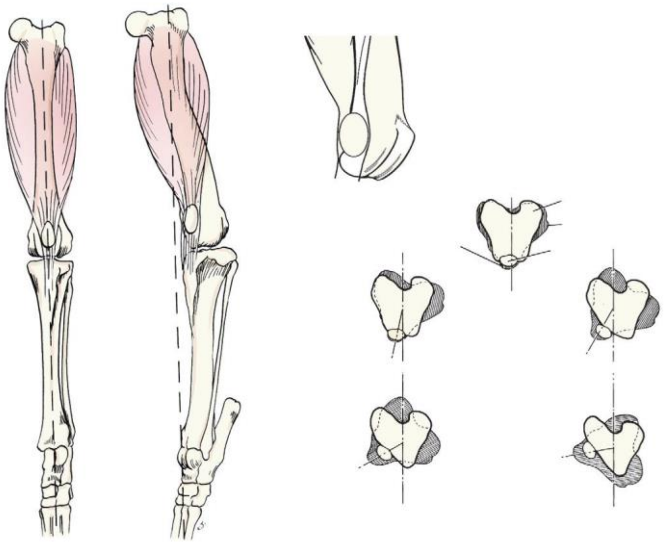

Figure 2 Bone deformity associated with grade medial patellar luxation (Kowaleski et al., 2012)

Diagnosis of patellar luxation based on palpation of patella and stifle of the affected hindlimb. The palpation must be done through complete range of motion. However, in obese and overweight animals, the patellar is usually difficult to be located upon palpation due layers of overlying fat. Still, the patellar ligament which is always palpable indirectly suggest the position of the patella. Radiographs are less common for the patellar luxation diagnosis, but might be necessarily required to confirm the patellar luxation in obese animals (Roush, 1993).



2.1.4 Treatment of patellar luxation

The patellar luxation can be treated both conventionally and surgically, depending on clinical signs, physical examination and age of dogs. Conventional treatment is suitable for asymptomatic patients or old dogs while surgical option for critical signs of lameness and young dogs with growth plates still growing. The surgical treatment aims to improve extensor mechanism realignment of the stifle as well as reposition and stabilize the patellar in the femoral trochlear groove (Wangdee et al., 2013). The surgical treatment of patellar luxation is a combination of soft tissue and bone reconstructions. Important techniques of soft tissue reconstruction include desmotomy, retinaculum and fascia overlap or imbrication, anti-rotational suture and quadriceps release. Bone reconstruction applied to correct skeletal deformity (internal rotation of the tibial crest and shallow of femoral groove) are trochleoplasty and transposition of the tibial tuberosity (L'Eplattenier, 2002) Correction of angular limb deformities is also necessary in the most severe cases (Linney et al., 2011). Postoperative management depends on surgical techniques that use for correction. Dogs should be on restricted activity 3-4 weeks after capsular imbrication or 6-8 weeks after trochleoplasty or tibial crest transposition.

After surgery procedure lead to restrict of range of motion because open wounds over joints that are allowed to heal secondarily by contraction and epithelialization may result in limitations to passive ROM. Surgical incisions may result in adhesions and fibrosis between skin, subcutaneous tissues, fascia, muscles, and bone, limiting the ability of tissues to glide over one another. Musculotendinous tissue may also be relatively shortened as a result of spasm or contracture. Any restriction of motion may result in resistance to joint movement and pain (Millis and Levine, 2014)

There are some studies with objective measures in clinical sign investigation and surgical outcomes in dogs with MPL. Surgical outcomes Pomeranians are effectively evaluated using lameness score as subjective measurement (Wangdee et al., 2013). Effects of physical therapy program in dogs after MPL surgical correction have been reported, relying on lameness score and ground force reaction in small-breed dogs (Wiputhanuphongs et al., 2015). The appropriate use of two-dimensional Kinematic method also monitor the range of motion compared between MPL and normal dogs (Klinhom et al., 2015).

## 2.2 Locomotion

Gait is a series of repeated strides, describes as cycle body movement that starts with one foot contact the ground until same foot contact ground again. There are several forms of gait to explain movement of each stride which is divided into two major characteristics. Symmetrical gait consists the walk, trot and pace. Asymmetric gaits consist the rack and gallop or canter. The trot, in stride have movement diagonal forelimb and hindlimb followed by two limbs supported, and the both sides of limbs is symmetrically moved.

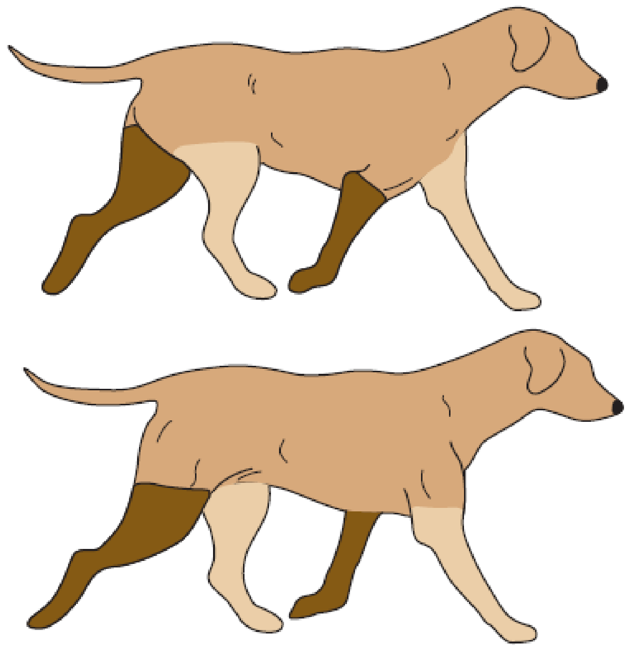

Figure 3 The trot. The limbs in light brown are in the stance phase, while the dark brown limbs are in the swing phase (Gillette and Angle, 2014)

2.3 Range of motion (ROM)

Range of motion (ROM) is the full motion of joint can be moved influence by the structure of the joint and soft tissues surrounding the joint. ROM is important to enhance or maintain compatibility of joint function (Carr et al., 2013). It related with flexibility and is affected by dog activity (Marcellin-Little and Levine, 2015). Differences condition can restrict joint motion ,major adversely affected to structure in joint articular cartilage and joint capsule including ligament, tendon, skeleton muscle and bone (Millard et al., 2010). The measure of joint motion is performed by using a goniometer. Mostly, in clinical practical focus on sagittal plane is primary motion (flexion and extension), the secondary or ancillary motion consist of coronal plane (adduction and abduction) and transverse plane (internal and external rotation). limit of secondary motion is less affected to limb than flexion or extension (Marcellin-Little and Levine, 2015).

ROM exercises are ideal for diminishing the effects of disuse and immobilization of the joint. To maintain ROM, the joints and muscles must be moved through their available ranges. Movement may be passive, active assisted, or active ROM exercises beneficially maintain the articular cartilage, muscles, ligaments and tendons in a healthy state. Passive ROM, normally performed by a physical therapist, is the motion of a joint occurring without muscle contraction within the available ROM. Once the patient's ROM improvement of a certain joint is achieved, it is necessary to continuously perform passive ROM and joint stretching exercises to produce as complete ROM as possible. Through this increased motion with the help of Passive ROM, active ROM is con-practically required to emphasize more complete use of the limb. Therefore, for those exercises, a transition between active assisted and active ROM may be necessary. Active ROM exercises may be a prelude to other strengthening activities. Owners may also be required to participate in active ROM exercises in helping with a home care program for their pet (Albright, 2014).

The target of the physical therapy to reduce pain and preserve normal range of motion of affected limb (Durant et al., 2011). The activity provide greater and difference ROM combine with work and trotting are benefited for affected limb which recovering from surgery (Marsolais et al., 2003; Carr et al., 2013).

Currently, in clinical practice play attention on ROM in dog, there are several studies investigated ROM in dog by using kinematic gait analysis in normal dog during walking and trotting (DeCamp et al., 1993; Allen et al., 1994; Hottinger et al., 1996). Walk provide a little ROM of total available range of motion about one-third of total range of motion, while trotting exercise increase 5 degree of range of motion for each joint, except stifle joint which add more 20 degree compare with walking (Durant et al., 2011). In addition, there are several studies to assess activity which can enhance ROM in dog. Holler et al. (2010) assess kinematic joint of the forelimb and hind limb between exercise regimen during walking on inclined slope, decline slope and over low obstacle (cavaletti) compare with walking on horizontal surface, the result indicated walking on incline surface and low obstacle is a specific physical therapy for dogs. Kinematic analysis of ROM was conducted previous in various activities, such as stair climbing or swimming. The range of motion of forelimb and pelvic limb is investigated during as ascent stair compare trotting on ground surface. The study found ramp provide increase in range of motion of forelimb and pelvic limb (Millard et al., 2010; Durant et al., 2011; Carr et al., 2013). Swimming provide greater range of motion of stifle and hip joint compare with walk in dog underdone surgical correction of cranial cruciate ligament rupture (Marsolais et al., 2003).



## 2.4 Kinematic Gait analysis

Subjective measurements of musculoskeletal function have been re-practiced for decades. When a person is curious to observe, and discover, his subject knowledge, collection of data and significantly relevant measurement tools will help improve and evaluate the precision. Observational gait analysis once seemed to be a difficult subject to assess due to varying gait patterns perceived in minute data. Only some kinematic variables could be observed and compared. Many studies had limited results until objective tools for gait pattern measurement were invented. Objective measures of musculoskeletal function were developed in 1800s. As a result, technology evolution impressively improves accuracy of gait analysis and measurement by helping observers perform more effective investigation. We could finally observe and assess temporospatial gait characteristics, which have become the backbone of our understanding of canine gait patterns (Gillette and Angle, 2008).

Kinesiology is a scientific study of motion divided into two dynamic patterns; kinetic and kinematic. Kinetic describes the force performing during the motion of limb whereas kinematic concerns with the body movement. Most gait analysis laboratories nowadays are equipped with reliable objective measures, such as a ground reaction force measurement platform, a computer-assisted measurement, a three-dimensional kinematic gait analysis system, electromyography and electro goniometry. Computer-assisted measurement and the force plate are the two most important tools for kinematic and kinetic investigation (DeCamp, 1997).

Kinematic describes the motion of body in space. Kinematic parameters involve position, velocity, acceleration, angles of anatomical point and body segment and joint in space. It provides information of musculoskeletal system, lameness, assessment of surgical techniques and medical treatments. Kinematic collects data of motion in both two and three dimensions. The highly-priced three dimensional kinematic which comes with quality equipment and software can produce complete data and accuracy. A specialist to perform with the system is required. The two-dimensional kinematic, on the other hand, has limited ability to collect rotational and circumduction data. The less-expensive model works at its best accuracy and repeatability when used to investigate canine hind limbs (Kim et al., 2008).

Conventional kinematic analysis systems perform by tracking the markers through different planes, using a video recorder to get a continuous image representing scenes in motion. From the tracking position, the software program will start calculating by using mathematical formulas and showing result assign numerical data of motion for quantitative gait analysis.

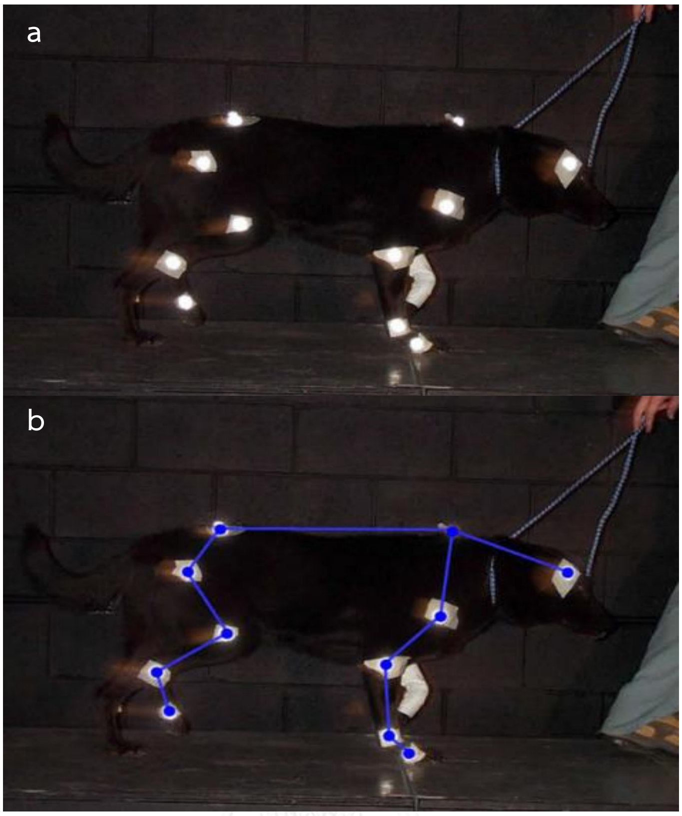


Figure 4 (a) Retroreflective markers have been placed on the dog bilaterally at the designated anatomical points. (b) The kinematic software identifies the markers (Gillette and Angle, 2008).

2.5 Kinovea program

Kinovea program is a motion analysis computer program. It was performed to analysis comparison and evaluation the movement in human via received data from image of video record by measure the range motion of the joint (Guzmán-Valdivia et al., 2013; Ali et al., 2015; Elwardany et al., 2015). There are several studies investigate validity and reliability of kinovea computer program in human, such as There are study to evaluate validity and reliability of kinovea method for measurements of flight time and vertical jump height in human. They found the kinovea provide not difference expensive tools such as infrared system platform (Balsalobre-Fernandez et al., 2014). The Kinovea software program was excellent reliable in both intra-rater and inter-rater reliability in measuring cervical range of motion in sagittal plane (Elwardany et al., 2015). It also comes agreement with Ali et al. (2015), using kinovea for  measure dominant wrist joint range of motion. The result demonstrate no statistical significant difference in both inter-rater and intra-rater reliability after using Kinovea software measurement of wrist (Ali et al., 2015).

# CHAPTER III
# MATERIALS AND METHODS

## 3.1 Animal

1. Twenty Pomeranian dogs presented with MPL grade 3. The study performed at Small Animal Teaching Hospital, Faculty of Veterinary Sciences, Chulalongkorn University. All dogs were efficiently assessed with complete physical examination, orthopedic examination, complete blood count, standard blood chemical profiles and accurate pelvic limb radiographs to rule out other orthopedic disorders. Informed owner consent must be obtained prior to dog participation in the study.
2. Five healthy Pomeranians dogs were collected kinematic data to investigate the range of motion for comparing with MPL dog.

### 3.1.1 Inclusion criteria

1. Pomeranian breed dogs between 1-5 years of age with normal patellar and grade 3 MPL
2. Dog owners participate in the training section in which dogs learnt to walk and trot on the treadmill.
3. Dogs with acceptance and tolerance to the non-slipping socks.

### 3.1.2 Exclusion criteria

1. Dogs developing systemic illness during the study
2. Dogs with other orthopedic disorder or any orthopedic surgical treatment involved
3. Bitches during pregnancy and lactation
4. Dogs with neurological deficit sign

5. Dogs with no tolerance to footwear which, in this study, was socks.
6. Dogs with complications and adverse effects from wearing non-slipping socks and/or surgical correction.

3.2 Study protocol

Dogs with grade 3 MPL cases generally require surgical treatment. Dogs were divided into two groups; control group (non-socks wearing) (n=10), and experimental group (socks wearing) (n=10). In experimental group, we collect data while non-wearing non-slipping socks (Experimental A: Ex A) and while wearing non-slipping socks (Experimental B group: Ex B). Socks were applied in dogs of the experimental group during trotting on treadmill start on the 14th day after the surgical correction. Both group were brought to walk and trotting 10 minutes for three times per week on treadmill. This scheduled activity was repeatedly for 8 weeks. Clinical outcomes were assessed by parameters of the following data obtained: Kinematic Data: Range of motion (ROM), maximum extension angle (MEA) and maximum flexion angle (MFA) were performed. Range of motion of the stifle joint using goniometer and lameness scores were collect 5 times; prior to surgery and 2, 4, 6, and 8 weeks after surgery, respectively. Five healthy Pomeranians dogs were collected kinematic data to investigate range of motion for comparing with MPL dog. Comparison have 2 categorical

Comparison within group

1. Control group
2. Experimental A group
3. Experimental B group

Comparison between group

1. Control group and experimental group A
2. Control group and experimental group A
3. experimental group A and experimental group B

Table 1 Evaluation schedule

| Clinical evaluation | First visit | Postoperative (Week) | | | |
|---|---|---|---|---|---|
| | | 2 | 4 | 6 | 8 |
| Physical examinations and orthopedic examinations | ✓ | | | | |
| Blood examination | ✓ | | | | |
| X-ray of pelvic limb | ✓ | | | | |
| Training dog walk and trotting on treadmill | ✓ | | | | |
| Collect kinematic data | ✓ | ✓ | ✓ | ✓ | ✓ |
| Lameness score | ✓ | ✓ | ✓ | ✓ | ✓ |
| Passive range of motion | ✓ | ✓ | ✓ | ✓ | ✓ |

3.2.1 Anesthesia

1. Food and water are withheld from dogs for 12 hours and 6 hours respectively prior to premedication.
2. Acepromazine (0.02-0.03 mg/kg) and morphine (0.3-0.5 mg/kg) are administered intramuscularly for premedication.
3. Fifteen to thirty minutes after premedication, an intravenous (IV) catheter is inserted into the cephalic vein. Anesthesia is induced by Propofol (4-8 mg/kg) IV and maintained with isoflurane in 100% oxygen. Cefazolin (25mg/kg) IV is administered as prophylactic antibiotic.
4. The dogs are positioned in sternal recumbency with extended pelvic limb stretched cranially. Dogs' hair over the lumbosacral space is clipped. Bupivacaine (1 mg/kg) and morphine (1mg/kg) are administered in epidural space.
5. All of them received carprofen (4.4 mg/kg) for the first 10 days and cephalexin (25 mg/kg) for the first 7 day after the surgery.

3.2.2 Surgical Procedures for Correction of MPL

Decision making and surgical techniques depend on patients' severity of the luxation and surgeon preference. Surgical correction of medial patellar luxation is a combination of soft tissue and bone reconstruction treatments. Soft tissue reconstruction techniques include desmotomy, retinaculum, fascia lata overlap (imbrication), anti-rotational suture and quadriceps release, whereas bone reconstruction procedures involve femoral trochleoplasty and tibial tuberosity transposition. Administration of seven-day cefazolin (25 mg/kg) and 2 weeks carprofen (4 mg/kg) are done postoperatively. Cryotherapy is performed at home. The dogs are restricted to short leash walks for six weeks.

3.3 Clinical outcome measurement

3.3.1 Kinematic data analysis

3.3.1.1 Kinematic Parameters

Kinematic parameters are data of the range of motion obtained from maximum flexion angle (MFA) and maximum extension angle (MEA) movements, determined for the hip, stifle, and tarsal joints in the sagittal plane.



3.3.1.2 Walking and Trotting on Treadmill Training Session

All dogs were trained to walk and trot on a treadmill before kinematic data of constant gait speed and habituation to treadmill trotting were collected. The training protocol starts seven days before collecting of the kinematic data. The dogs were trained to trot on a treadmill at a frequency of 3 to 9 sessions per day for approximately 3– 5 minutes, with 2 or 3 time repetitions (Miqueleto et al., 2013). The dogs were lead on a leash by a handler positioned at the front of the treadmill. Dogs were first trained to stand on the treadmill set at a very low speed that gradually increased and eventually reached the normal walking and trotting gait level. The dogs who cannot reach constant gait level on the treadmill were excluded from the study.

3.3.1.3 Video-Based Kinematic Data Collection

In this study, three cameras used to collect two-dimensional kinematic data are Sony AS200V. In order to capture most excellent sample data possible, all cameras are primarily set at a high-resolution of 1280x720 120 Hz. Two of them were positioned at the 0.5-meter distance, left and right aside the treadmill to horizontally record the sagittal plane movement, as one separately attached above the center of the treadmill at one-meter distance from the floor to vertically record the dorsal plane motion, and to make sure the trotting dog was in the center of the treadmill. Prior to kinematic data completely collected, the system was calibrated by the filming of four reflexive targets fixed in one picture for the recognition of the coordinate in the test space using a motion analysis computer software, 0.8.24-versioned Kinovea. The experiment was performed on the treadmill with trotting gait. Speed started at a low setting and increased slowly until speed reach 1.11 m/s (Klinhom et al., 2015) with the dog achieved trotting gait. All dogs were controlled on the leash by the same handler. Kinematic data were recorded and analyzed by 0.8.24-versioned Kinovea, the accurate and reliable motion analysis software program. Each dog's five static trials performed in the center of the treadmill to maintain gait consistency were collected. Trials happening out of the center of the treadmill were excluded. Kinematic data derived from ROM, maximum extension angle (MEA) and maximum flexion angle (MFA) of the hind limb joint were measure and corrected.

Figure 5 Kinematic system and cameras position for recording the kinematic data on top view

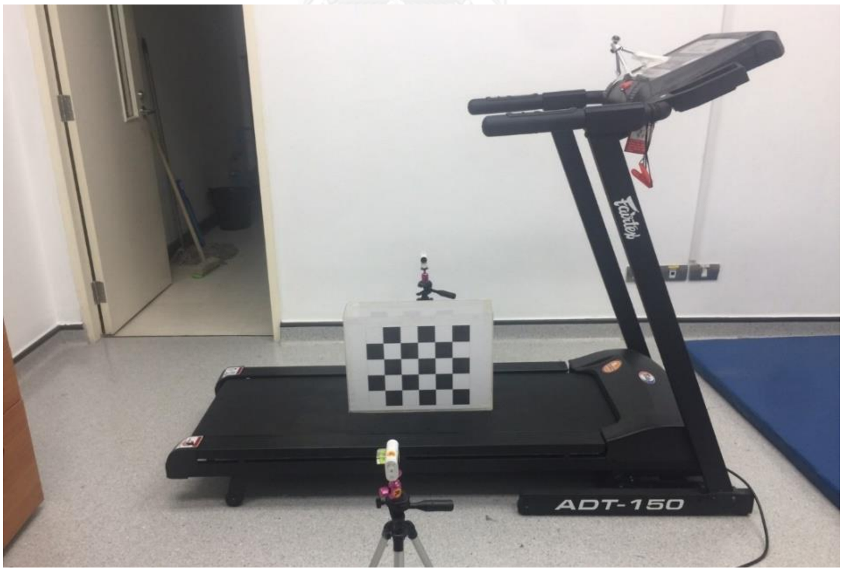


Figure 6 Kinematic system and cameras position for recording the kinematic data on side

3.3.1.4 Marker placement

In this study, kinematic markers for the hind limb were placed on the anatomical landmark of left and right sides of the pelvic limbs. This significant action was conducted by the same researcher. Five anatomical landmarks placed with markers are distal end of the fifth metatarsal bone, the lateral malleolus, the lateral epicondyle of the femur, the greater trochanter and the dorsal iliac spine. Spherical non-reflective markers with 1 cm diameter were tagged on the dog skin using double-sided adhesive tape on the skin area where the hair was clipped. Further, extension and flexion of the joint were manually performed after the application of the markers to confirm close position between the markers and the joint center (Miqueleto et al., 2013)

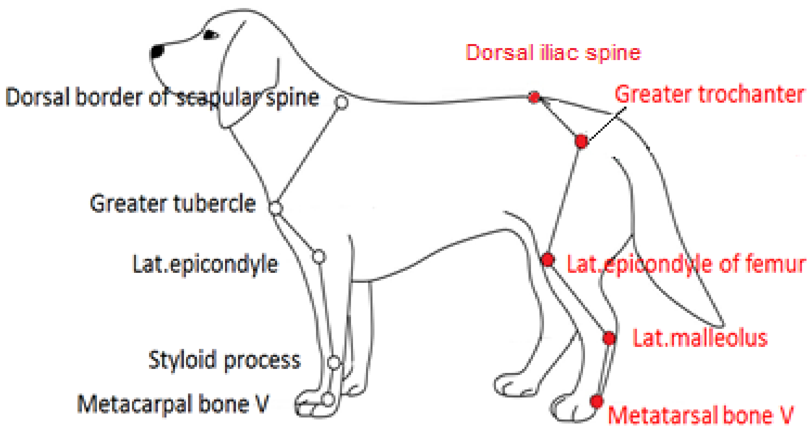


Figure 7 Anatomical Landmarks for Marker Replacement of the Pelvic Limb

3.3.2 Passive Range of motion

In this study, range of motion (ROM) was measured by using a traditional goniometer, during joint flexion and extension movements. The joint slowly flexed and extended within the comfortable range of motion until the first sign of discomfort such as dogs pulling the limb away, tensing the muscles or turning the head was noted. ROM measurement was performed with a mean of 3 times during the study. The goniometer was placed over the fulcrum of the stifle joint. Of the two moveable arms of goniometer, the proximal arm was straight to the greater trochanter and the distal one was appareled to the tibia. The joint was slowly flexed until the first indication of discomfort, then slowly extended until the first indication of discomfort was noted. These angles were recorded.

3.3.3 Lameness score

Lameness score was evaluated for subjective measurement at preoperative and postoperative at 2, 4, 6 and 8 weeks by the same person at each time. Follow by table 2.

Table 2 Lameness score (Hazewinkel et al., 2008)

| Lameness score | definition |
|---|---|
| 0 | no lameness |
| 1 | mild lameness; normal at a walk with mild lameness at a trot |
| 2 | moderate lameness; consistent lameness at a walk with pronounced lameness at a trot |
| 3 | severe lameness; toe-touching to some weight bearing at a walk, non-weight bearing trot |
| 4 | non-weight bearing lameness |

### 3.4 Statistical analysis

Kinematic data: ROM, MEA, MFA and PROM at preoperative and postoperative value were reported as mean ± S.D. The lameness score was reported as median. Comparing the kinematic data between control and experimental group and within experimental group were used repeated measure analysis of variance (ANOVA). Statistical analysis was implemented by using the statistic package SPSS program (version 22.0.0, IBM Corp.) For all comparison, p values < 0.05 was considered statistical significant.

# CHAPTER IV
# RESULTS

## 4.1 Animal

Twenty Pomeranians and two normal Pomeranians had undergone surgical correction of medial patellar luxation were included in this study that enrolled fit the inclusion criteria. 20 Pomeranians MPL divided into 2 groups: control group (n=10 legs) and experimental group (Ex A and Ex B) (n=10 legs). The Mean ± SD body weight, body condition score (BCS) and age was 3.13±1.00 Kg., 3.10±0.21, 2.57±1.67 years, respectively for the control group and 3.20±0.88 Kg., 3.05±0.16, 2.14±1.86 years for the experimental group, respectively. There is no significant different between groups by means of weights, BSC and age. Two Pomeranians (4 legs) dogs were collected the normal kinematic data to investigated the normal range of motion in this breed for comparing with MPL dogs.

Table 3 Mean±SD of weight, age and BCS of Pomeranians in the control, experimental and normal group.

| VARIABLE | WEIGHT (KG.) | BCS | AGE(YEARS) |
|---|---|---|---|
| CONTROL GROUP (N=10) | 3.13±1.00 | 3.10±0.21 | 2.57±1.67 |
| EXPERIMETAL GROUP (N=10) | 3.20±0.88 | 3.05±0.16 | 2.14±1.86 |
| NORMAL STIFLE (N=4) | 2.80±0.28 | 3.00±0 | 1.75±0.35 |

## 4.2 Kinematic data analysis

### 4.2.1 Comparison within group

All data were in the normal distribution. Mean ± SD of MEA, MFA and ROM in each group were shown in Table 4, 5 and 6. Comparison kinematic data among period of time in each group.

**Comparison within the control group,** there was no significant difference of the hip and hock joints in the control group among the period of time. The MEA of

Stifle joint in week 8 was significant higher compare week 2 and 4 postoperative (table 4).

**Comparison within the experimental A group** (Ex A), there was no significant difference of the hock joint. The MEA of the hip joint in week 4 was significantly higher compared with before surgery. The MEA of the Stifle joint before surgery and week 2 was significantly lower compared with week 4, 6 and 8 (table 5).

**Comparison within the experimental B group** (Ex B), there was no significant difference of the hock. The MEA and ROM of hip joint significantly lower at week 6 compared with week 2. The MFA of stifle joint in week 6 significantly higher among with week 2. The MFA of stifle joint in week 2 and 4 significantly higher among with week 6 and 8. (table 6).

4.2.2 Comparison between groups

**Comparison between the control group and the experimental A group**, the MEA MFA and ROM of the hip and hock joints were not significantly in compared between the control and the experimental group. The MEA of stifle joint was significantly greater in the experimental group at week 4 and 6 compared with control group. In addition, The ROM of the stifle joint was significantly different in week 8, however, no statistical differences were detected in the MFA between groups (table 7).

**Comparison between the control group and the experimental B group,** the MEA MFA and ROM of the hip and hock joint were no significant compare between control and experimental B group. In the stifle joint, MEA in week fourth was significant greater in experimental group compare with control group. MFA of stifle at week 4 and 8 in experimental group was significant lower than control group. The ROM was significant higher in week 2 and 4 compare between group (table 8).

**Comparison between the experimental A group and the experimental B group,** the MEA MFA and ROM of the hip and hock joints were not significantly different between both groups. There was significantly greater ROM and MFA of stifle joint in week 2 and 4 (table 9).

Table 4 Comparison of MEA, MFA and ROM in the control

| | Position | | MEA | MFA | ROM |
|---|---|---|---|---|---|
| Hip joint | Before surgery | | 133.88±4.84 | 108.163±6.16 | 25.142±4.59 |
| | postoperative | Week 2 | 133.07±5.62 | 109.434±5.33 | 23.637±3.2 |
| | | Week 4 | 134.32±6.26 | 108.177±3.28 | 26.133±4.51 |
| | | Week 6 | 132.53±7.71 | 108.472±6.18 | 24.061±4.97 |
| | | Week 8 | 134.712±6.95 | 108.868±7.72 | 25.856±4.44 |
| Stifle joint | Before surgery | | 153.47±5.96 [a] | 100.90±7.13 | 52.078±4.42 |
| | postoperative | Week 2 | 153.62±6.73[a] | 105.47±8.11 | 51.15±7.65 |
| | | Week 4 | 153.34±6.11[a] | 101.22±8.68 | 49.2±9.5 |
| | | Week 6 | 154.19±5.27 | 101.00±3.95 | 51.74±8.24 |
| | | Week 8 | 160.07±5.49[b] | 106.03±6.92 | 53.42±6.72 |
| Hock joint | Before surgery | | 165.81±6.63 | 123.04±9.105 | 42.77±3.83 |
| | postoperative | Week 2 | 167.28±8.2 | 127.64±10.2 | 39.645±6.7 |
| | | Week 4 | 169.23±6.31 | 125.78±10.91 | 43.448±8.3 |
| | | Week 6 | 165.96±7.48 | 127.34±7.97 | 38.141±4.41 |
| | | Week 8 | 170.88±6.85 | 132.25±8.59 | 38.625±5.97 |

[a, b, c] Value in each column and each joint with different letter superscripts were significantly different. ($P < 0.05$).

Table 5 Comparison of MEA, MFA, ROM in the Experimental A group.

| Joint | | Position | MEA | MFA | ROM |
|---|---|---|---|---|---|
| Hip joint | Before surgery | | $128.47 \pm 14.5^{a}$ | 108.70±13.8 | 20.09±4.33 |
| | postoperative | Week 2 | 137.28±9.21 | 114.33±8.91 | 22.96±5.16 |
| | | Week 4 | $138.30 \pm 11.6^{b}$ | 114.86±11.9 | 23.75±3.75 |
| | | Week 6 | 130.35±11.36 | 108.85±13.38 | 21.30±3.30 |
| | | Week 8 | 134.66±10.42 | 111.17±11.99 | 23.44±5.05 |
| Stifle joint | Before surgery | | $152.72 \pm 5.75^{ab}$ | 103.53±3.88 | $49.22 \pm 5.82^{a}$ |
| | postoperative | Week 2 | $153.44 \pm 6.06^{c}$ | 103.82±7.49 | $49.62 \pm 10.43^{ac}$ |
| | | Week 4 | $161.11 \pm 7.70^{c}$ | $109.57 \pm 11.72^{a}$ | $51.53 \pm 6.68^{ad}$ |
| | | Week 6 | $161.04 \pm 3.50^{c}$ | 104.76±6.4 | $56.28 \pm 7.57^{ab}$ |
| | | Week 8 | $162.35 \pm .4.63^{c}$ | $100.01 \pm 9.45^{b}$ | $62.34 \pm 12.07^{b}$ |
| Hock joint | Before surgery | | 168.17±10.09 | 128.88±10.36 | 39.48±7.9 |
| | postoperative | Week 2 | 169.63±10.84 | 130.55±12.66 | 39.64±6.7 |
| | | Week 4 | 173.61±10.38 | 136.60±13.13 | 43.44±8.3 |
| | | Week 6 | 170.41±8.18 | 132.93±12.50 | 38.14±4.41 |
| | | Week 8 | 168.21±10.11 | 125.98±15.60 | 38.62±5.97 |

MEA: maximum extension angle, MFA: maximum extension angle, ROM: range of motion

$^{a, b, c, d}$ Value in each column and each joint with different letter superscripts were significantly different ($P < 0.05$).

Table 6 Comparison of MEA, MFA, ROM in the Experimental B group

| | Position | | MEA | MFA | ROM |
|---|---|---|---|---|---|
| Hip joint | postoperative | Week 2 | $138.32\pm11.23^{a}$ | $112.46\pm9.62$ | $25.85\pm3.96^{a}$ |
| | | Week 4 | $137.17\pm10.2$ | $115.99\pm13.26$ | $23.44\pm4.37$ |
| | | Week 6 | $129.14\pm11.88^{b}$ | $107.63\pm12.63$ | $21.50\pm3.86^{b}$ |
| | | Week 8 | $133.10\pm8.04$ | $108.45\pm9.41$ | $24.64\pm5.57$ |
| Stifle joint | postoperative | Week 2 | $157.67\pm5.75$ | $90.38\pm5.06^{a}$ | $67.29\pm7.23^{a}$ |
| | | Week 4 | $160.48\pm9.38$ | $91.89\pm10.76$ | $68.59\pm11.09^{ac}$ |
| | | Week 6 | $157.20\pm13.2$ | $98.25\pm11.49^{b}$ | $58.94\pm8.39^{b}$ |
| | | Week 8 | $157.106\pm6.27$ | $97.48\pm11.22$ | $59.62\pm5.50^{b}$ |
| Hock joint | postoperative | Week 2 | $173.16\pm8.93$ | $131.63\pm14.45$ | $41.52\pm11.56$ |
| | | Week 4 | $172.04\pm11.13$ | $129.17\pm17.97$ | $42.86\pm13.29$ |
| | | Week 6 | $173.61\pm7.39$ | $133.05\pm10.48$ | $40.56\pm6.98$ |
| | | Week 8 | $170.94\pm10.36$ | $127.91\pm10.74$ | $43.02\pm5.82$ |

MEA: maximum extension angle, MFA: maximum extension angle, ROM: range of motion.

[a, b, c] Value in each column and each joint with different letter superscripts were significantly different $<0.05$

Table 7 Comparative maximum extension angle, maximum flexion angle and range of motion of stifle joint between the control group and the experimental B group.

| position | | | MEA | | | MFA | | | ROM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | time | control | Ex B | p-value | control | Ex B | p-value | control | Ex B | p-value |
| Hip joint | Postoperative | wk2 | 133.07±5.62 | 138.32±11.23 | 0.23 | 109.434±5.33 | 112.46±9.62 | 0.5 | 23.637±3.2 | 25.85±3.96 | 0.26 |
| | | wk4 | 134.32±6.26 | 137.17±10.2 | 0.51 | 108.177±3.28 | 115.99±13.26 | 0.08 | 26.133±4.51 | 23.44±4.37 | 0.17 |
| | | wk6 | 132.53±7.71 | 129.14±11.88 | 0.43 | 108.472±6.18 | 107.63±12.63 | 0.85 | 24.061±4.97 | 21.50±3.86 | 0.19 |
| | | wk8 | 134.712±6.95 | 133.10±8.04 | 0.71 | 108.868±7.72 | 108.45±9.41 | 0.92 | 25.856±4.44 | 24.64±5.57 | 0.54 |
| Stifle joint | Postoperative | wk2 | 153.62±6.73 | 157.67±5.75 | 0.20 | 105.47±8.11 | 90.38±5.06 | 0.0002* | 51.15±7.65 | 67.29±7.23 | 0.0001* |
| | | wk4 | 153.34±6.11 | 160.48±9.38 | 0.02* | 101.22±8.68 | 91.89±10.76 | 0.015* | 49.2±9.5 | 68.59±11.09 | 0.0001* |
| | | wk6 | 154.19±5.27 | 157.20±13.2 | 0.33 | 101.00±3.95 | 98.25±11.49 | 0.47 | 51.74±8.24 | 58.94±8.39 | 0.053 |
| | | wk8 | 160.07±5.49 | 157.106±6.27 | 0.34 | 106.03±6.92 | 97.48±11.22 | 0.025* | 53.42±6.72 | 59.62±5.50 | 0.09 |
| Hock joint | Postoperative | wk2 | 167.287±8.2 | 173.16±8.93 | 0.14 | 127.642±10.2 | 131.63±14.45 | 0.46 | 39.645±6.7 | 41.52±11.56 | 0.58 |
| | | wk4 | 169.239±6.31 | 172.04±11.13 | 0.48 | 125.789±10.91 | 129.17±17.97 | 0.53 | 43.448±8.3 | 42.86±13.29 | 0.86 |
| | | wk6 | 165.965±7.48 | 173.61±7.39 | 0.057 | 127.341±7.97 | 133.05±10.48 | 0.29 | 38.141±4.41 | 40.56±6.98 | 0.48 |
| | | wk8 | 170.881±6.85 | 170.94±10.36 | 0.98 | 132.254±8.59 | 127.91±10.74 | 0.42 | 38.625±5.97 | 43.02±5.82 | 0.2 |

MEA: Maximum extension angle, MFA:  Maximum extension angle, ROM: Range of motion, Ex B: experimental B

* Mean values significant ($P<0.05$) different between control group and experimental group in each joint

Table 8 Comparative maximum extension angle, maximum flexion angle and range of motion of stifle joint between the Exp A and the Exp B groups

| | position | | MEA | | | MFA | | | ROM | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | time | | Ex A | Ex B | p-value | Ex A | Ex B | p-value | Ex A | Ex B | p-value |
| Hip joint | Postoperative | wk2 | 137.28±9.21 | 138.32±11.23 | 0.81 | 114.33±8.91 | 112.46±9.62 | 0.67 | 22.96±5.16 | 25.85±3.96 | 0.14 |
| | | wk4 | 138.30±11.6 | 137.17±10.2 | 0.79 | 114.86±11.9 | 115.99±13.26 | 0.8 | 3.75±3.75 | 23.44±4.37 | 0.81 |
| | | wk6 | 130.35±11.36 | 129.14±11.88 | 0.77 | 108.85±13.38 | 107.63±12.63 | 0.78 | 21.3±3.30 | 21.50±3.86 | 0.92 |
| | | wk8 | 134.66±10.42 | 133.10±8.04 | 0.72 | 111.17±11.99 | 108.45±9.41 | 0.54 | 23.44±5.05 | 24.64±5.57 | 0.54 |
| Stifle joint | Postoperative | wk2 | 153.44±6.06[c] | 157.67±5.75 | 0.18 | 103.82±7.49 | 90.38±5.06 | 0.0007* | 49.62±10.43 | 67.29±7.23 | 0.0001* |
| | | wk4 | 161.11±7.70 | 160.48±9.38 | 0.84 | 109.57±11.72 | 91.89±10.76 | 0.0001* | 51.53±6.68 | 68.59±11.09 | 0.0001* |
| | | wk6 | 161.04±3.50 | 157.20±13.2 | 0.21 | 104.76±6.4 | 98.25±11.49 | 0.08 | 56.28±7.57 | 58.94±8.39 | 0.47 |
| | | wk8 | 162.35±.4.63 | 157.106±6.27 | 0.09 | 100.01±9.45 | 97.48±11.22 | 0.50 | 62.34±12.07 | 59.62±5.50 | 0.46 |
| Hock joint | postoperative | 2 | 169.63±10.84 | 173.16±8.93 | 0.37 | 130.55±12.66 | 131.63±14.45 | 0.84 | 38.59±7.01 | 41.52±11.56 | 0.39 |
| | | 4 | 173.61±10.38 | 172.04±11.13 | 0.69 | 136.60±13.13 | 129.17±17.97 | 0.17 | 37.01±7.9 | 42.86±13.29 | 0.08 |
| | | 6 | 170.41±8.18 | 173.61±7.39 | 0.42 | 132.93±12.50 | 133.05±10.48 | 0.98 | 37.57±5.6 | 40.56±6.98 | 0.38 |
| | | 8 | 168.21±10.11 | 170.94±10.36 | 0.49 | 125.98±15.60 | 127.91±10.74 | 0.72 | 42.37±6.29 | 43.02±5.82 | 0.84 |

MEA: maximum extension angle, MFA:  maximum extension angle, ROM: range of motion. Ex B: experimental B

* Mean values significant (P<0.05) different between control group and experimental group in each joint

Table 9 Comparison kinematic data between control group experimental group with normal stifle group

| Group | Control | | | | | Experimental | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Position | Pre-op | Wk2 | Wk4 | Wk6 | Wk8 | Pre-op | Wk2 | Wk4 | Wk6 | Wk8 |
| MEA | 153.39±5.96 | 152.93±6.56 | 153.17±6.11 | 154.69±5.12 | 160.38±6.56 | 152.72±5.75 | 153.44±6.06 | 161.11±7.70 | 161.04±3.50 | 162.34±4.63 |
| nMEA | ----------165.98±6.58---------- | | | | | | | | | |
| p-value | 0.005 | 0.006 | 0.005 | 0.005 | 0.124 | 0.003 | 0.005 | 0.291 | 0.234 | 0.261 |
| MFA | 100.90±7.13 | 105.47±8.11 | 101.22±8.68 | 101.00±3.95 | 106.03±6.92 | 103.53±3.88 | 103.82±7.49 | 109.57±11.72 | 104.76±6.4 | 100.01±9.45 |
| nMFA | ----------107.47± 3.01---------- | | | | | | | | | |
| p-value | 0.108 | 0.706 | 0.197 | 0.09 | 0.838 | 0.096 | 0.218 | 0.610 | 0.441 | 0.05 |
| ROM | 52.078±4.42 | 51.15±7.65 | 49.2±9.5 | 51.74±8.24 | 53.42±6.72 | 49.22±5.82 | 49.62±10.43 | 51.53±6.68 | 56.28±7.57 | 62.34±12.07 |
| nROM | ----------58.50±4.72---------- | | | | | | | | | |
| P-value | 0.037 | 0.117 | 0.103 | 0.156 | 0.207 | 0.016 | 0.134 | 0.084 | 0.600 | 0.409 |

nMEA: Maximum extension angle in normal dogs, nMFA: Maximum flexsion angle in normal dogs, nROM: Range of motion in normal dogs.

Mean values significant ($P<0.05$) different in each column between normal dogs and control/experimental group in stifle joint.

**Comparison between the control and the experimental groups with the normal group**

The purpose in comparison to prove the stifle was return to normal function compare with the normal range. The MEA MFA and ROM of the hip and hock joint were not found significantly between normal group and both groups The MFA of the stifle joint was not found significantly. The MEA in the control group was not found significantly in week 8 postoperative but the experimental group was not found significantly in week 4. The ROM of stifle joint was significantly only in preoperative compared with normal stifle (table 10).

4.3 Passive Range of motion

The PROM of the stifle joint compared between control and experimental groups. At the second week of the post-operative period, both groups had decreased extended PROM and PROM, and a little changed of the flexed motion. Stifle extension angle and ROM in experimental group provided greater than control group and continually increase until 8 week, but not significantly different.

Table 10 Mean±SD of extended PROM, Flexed PROM and PROM of the stifle joint.

| Position | | Extension | | | Flexion | | | PROM | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Time | | control | Ex group | p-value | control | Ex group | p-value | control | Ex group | p-value |
| before surgery | | 157.00 | 157.70 | 0.786 | 42.90 | 40.8 | 0.384 | 114.1 | 116.9 | 0.487 |
| After surgery | wk2 | 151.30 | 151.80 | 0.79 | 47.00 | 42.700 | 0.62 | 104.3 | 109.1 | 0.57 |
| | wk4 | 152.80 | 154.00 | 0.470 | 44.00 | 40.900 | 0.157 | 108.8 | 113.1 | 0.10 |
| | wk6 | 156.40 | 158.80 | 0.215 | 40.10 | 40.100 | 1.00 | 116.3 | 118.7 | 0.31 |
| | wk8 | 158.10 | 160.60 | 0.65 | 39.40 | 38.700 | 0.73 | 118.7 | 121.9 | 0.16 |

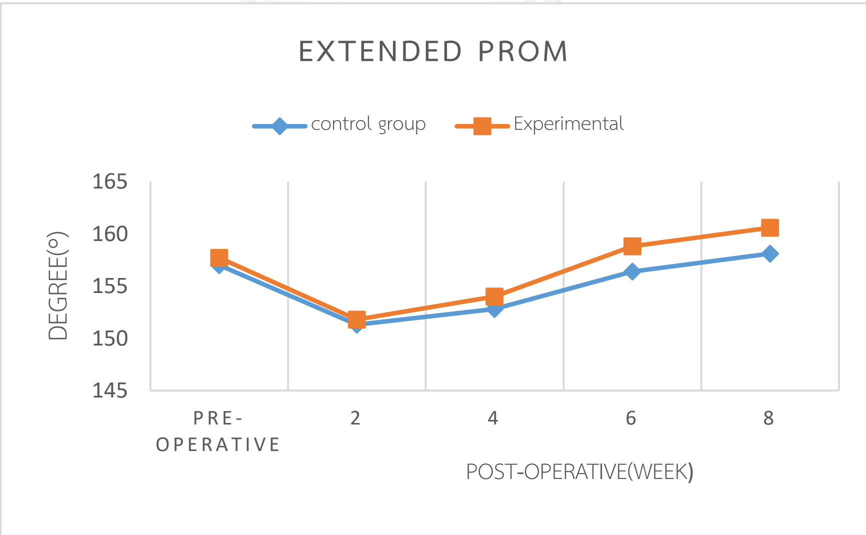


Figure 8 Comparison of the extended ROM between the control group and experimental

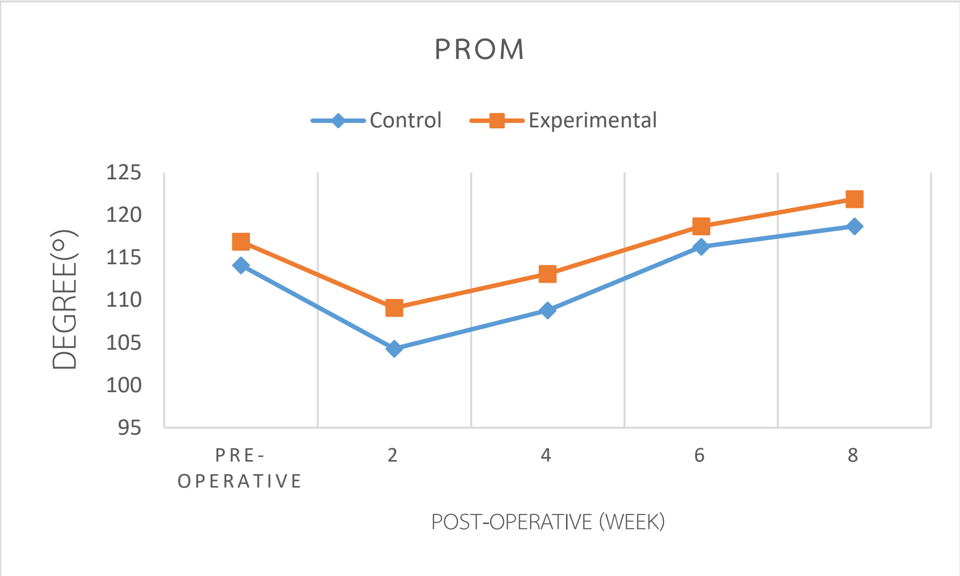


Figure 9 Comparison of the Flex ROM between the control group and experimental

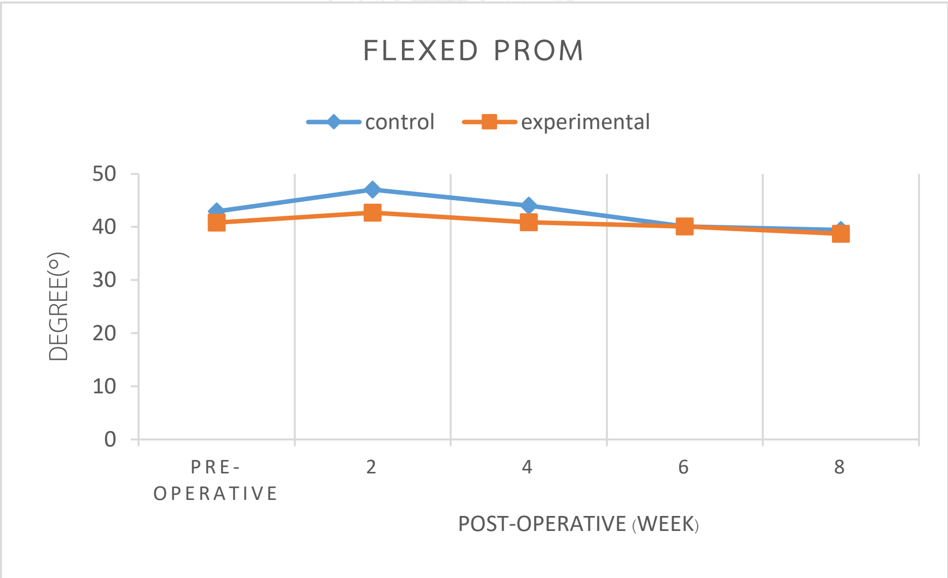


Figure 10 Comparison of the PROM between the control group and the experimental group

4.4 Lameness scores

The median of the lameness score before surgery and 2 week postoperative were not different between the control and the experimental group. At week 4, lameness score decrease in experimental group compare with control group. The lameness score was still detected in the control group while no detected in the experimental group.

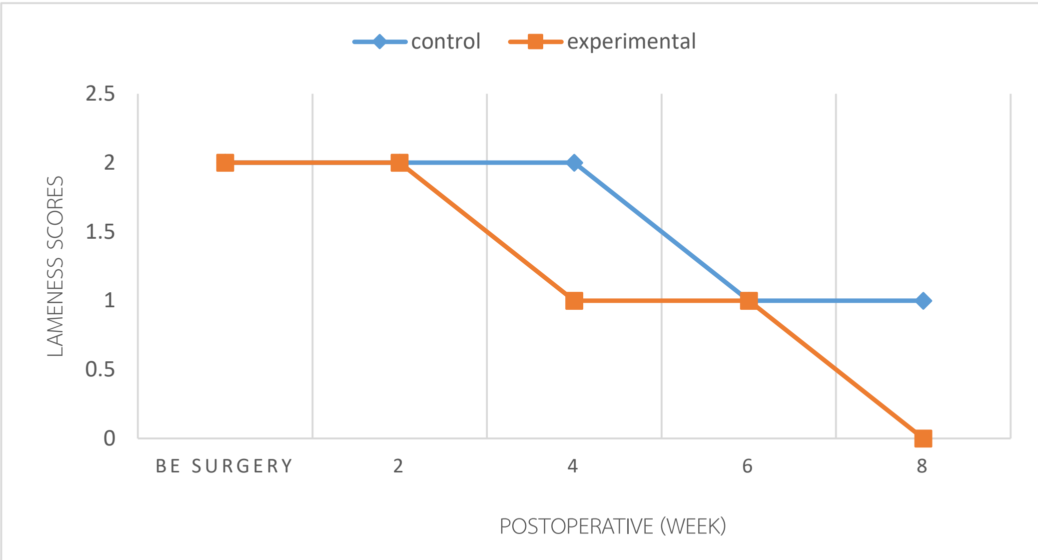


Figure 11 Lameness score of limbs before and after surgical correction of medial patellar luxation in Pomeranians grade 3.

Comparison of the difference of weight bearing between the physical therapy and the control groups. The graph showed greater improvement in the experimental group in week 4 and 8 postoperative.

Table 11 Lameness score of limbs before and after surgical correction of medial patellar luxation in Pomeranians grade 3

| Lameness score | Control | Experimental |
|---|---|---|
| Before surgery | 2<br>(1-3) | 2<br>(1-3) |
| week2 | 2<br>(1-3) | 2<br>(1-2) |
| week4 | 2<br>(1-2) | 1<br>(0-2) |
| week6 | 1<br>(1-2) | 1<br>(0-1) |
| week8 | 1<br>(0-1) | 0<br>(0-1) |

*value are shown as median (range).

# CHAPTER V
# DISCUSSION

Our study was performed in order to investigate the effective of non-slipping socks to increase the AROM in dogs undergone the MPL surgery as the practical method of rehabilitation program in the clinical practice. The non-slipping socks are widely available in Thailand and are commonly used in the indoor dogs to prevent any injury during playing and exciting. Application of non-slipping socks for the dogs undergone the stifle surgery may also apply for the client owners to practice in their house. The 2D kinematic study was studied and investigated the AROM by trotting on the treadmill. Due to the various breed conformation, body weight and body condition score are the primary factors which interfere the joint movement pattern, our study was mainly performed in only MPL Pomeranian to decrease the other factors. However, the varied standards of Pomeranian in Thailand are commonly found, the unexpected kinematic data were identified in our study.

Our 2 D kinematic study was investigated in two groups which were the control group (Pomeranian undergone MPL surgery) and the experimental group (Pomeranian undergone MPL surgery while they did not wear the non-slipping socks and while they did wear the non-slipping socks. The experimental groups were divided as Ex A and Ex B in order to decrease the individual factors which may interfere to our kinematic data.

In our study, the kinematic data, PROM and lameness scores of the pelvic limbs in Pomeranians with MPL grade 3 were investigated. The MPL surgical procedures were performed by the same two surgeons with the same types of the procedures including the soft tissue and bone reconstruction techniques. However, the skill, surgical techniques, the surgical duration, and the severity of soft tissue injuries were also different depending on the surgeons and the patients.

Twenty-two Pomeranians were enrolled to our study. There were not statistical different between the control, the experimental group A, B and normal by means of the factors of body weight, body condition score and age.  Only two normal stifles

Pomeranians were included in our study due to the high incidences of MPL Pomeranians were found in Thailand.

In the control group, the MEA of the stifle joint significantly decreased in preoperative, week 2 and 4 postoperative. We hypothesized that MPL dogs always had restrict ROM due to abnormal alignment of quadriceps muscle group resulting to decrease of extensor mechanism as the same manner as the dogs undergone stifle surgery had restriction of ROM.

In the experimental group, we collected 2D kinematic data while they did not wear socks (ex A) to assess outcome and while wearing the non-slipping socks (ex B) for investigation the effect of non-slipping socks on AROM. The control group and the EX A group were compared in the same of time. The results revealed that the MEA of the stifle joint had greater EX A than those in the control group. The results revealed the non-slipping socks can be applied to increase AROM which promote the joint healing and return to normal extensor mechanism.

The Comparison between the control and the EX B. It was found that the MFA of the stifle were decreased may resulting to increase ROM. We suggested that the exercise with non-slipping socks promoted flexion of joint. However, the comparison may have many variable factors due to the individual factor. Therefore, the comparison between the EX A and EX B of experimental group reduced variation due to the data collection from the same dog was performed to decreased the individual factor. The results showed that dogs wearing socks (EX B) had decrease the MFA of the stifle joint and may result increase ROM

As a result of our study, the kinematic data of hip and hock joints were not found significant difference in comparison between of both groups. Therefore, dogs with orthopedic problems with limited ROM of hip or hock joints may likely not benefit from using non-slipping socks during trotting and walking exercise as therapeutic rehabilitation to increase ROM.

Our results indicated that trotting exercise during wearing socks is benefit activity to provide greater motion of extension and ROM of stifle joint in Pomeranians undergone surgical correction MPL. After surgical correction of MPL as restricted ROM condition, which required activity to increase motion more than walk or trotting in level surface (Marsolais et al., 2003; Carr et al., 2013). MPL dogs always had restrict ROM due to abnormal alignment of quadriceps muscle group result to decrease of extensor mechanism. Thus, AROM exercise may be benefit of dog in restrict ROM condition.

However, the trotting exercise with non-slipping socks can provide greater MFA of the stifle joint, which improper to use at first period of postoperative in some surgical correction such as tibial plateau leveling osteotomy (TPLO) and tibial tuberosity advancement (TTA) because these surgeries have occurred to the patellar ligament. The exceed flexion of the stifle joint cause increase stress to moment arm of the stifle joint (Holler et al., 2010).

The exercise started on the 14th day after the surgical correction because AROM exercise required the greater strength of muscle (Millis and Levine, 2014). We used trotting gait in this study because it provided greater joint excursion of each joint approximately five degree except in stifle joint can be increased approximately 20 degrees of motion as compared with walking (Durant et al., 2011). Therefore, we would like to investigate the greater excursion of trotting when using non-slipping socks.

In our study, we use human treadmill that the surface of treadmill was not conveniently designed for animal. It may effect on the dog habituation on the treadmill. Moreover, there is no study in habituation on treadmill in small breed. Habituation to the treadmill had been evaluated only in large breed dog (Brebner et al., 2006; Fanchon et al., 2006). In our study, we used the speed at 1.06-1.22 m/s which is in same range of the previous study that used treadmill speed at 1.11 m/s in Chihuahuas (Klinhom et al., 2015). There is no study in variation of velocity on treadmill in small breed but those in large breed dogs indicated that increasing trotting velocity lead to an increase in angular displacement (Hottinger et al., 1996). In this study, speed used on the treadmill considered from trotting posture that comfortable, steady and repeatable gait in each dog.

Kinematic evolution is objective tool of measuring joint motion. Two-dimension kinematic analysis use in this study. Comparing with three-dimension some movements may be missing because only sagittal plan is quantified. However, there were many studies reported about the 2D system that it was accurate and repeatable data when measuring canine pelvic limbs in sagittal plane (Feeney et al., 2007; Kim et al., 2008).

The PROM and lameness scores had better clinical outcomes in experimental group compared with the control group. Our clinical outcomes were synchronized to the kinematic data. Outcome of kinematic data of both groups at 8 weeks after postoperative were return to normal value. There was no statistic significant different between week-8 of postoperative surgically MPL dogs and normal dogs similar to previous study that evaluated the results of surgery for Pomeranian which MPL (Wangdee et al., 2013). However, the normal dogs recruit in this study have only 2 Pomeranians (4 normal stifles) may not be good a representation of the normal dogs.

Our study used Pomeranians because we found the high incidence of MPL in this breed almost living in slippery floor, appropriated with using non-slipping socks, which may not be improper to extrapolate of data to other breeds.

There were several strengths in this study. First, the study was performed only Pomeranian breed which made the data in homogeneous sample size and reduce variation from different conformation. Finally, our kinematic data use the multiple trial in each Pomeranians result in more precision and validation of the kinematic data.

There were others aspect of limitations in the present study. First limitation is the skin motion artefact, dogs have movable skin compare to other species which may lead to misrepresentation of anatomic landmark of pelvic limb (Millard et al., 2010). This limitation is already constraint in the kinematic data collection although it is three-dimensional kinematic data. The second limitation is marker placement variation that is one of the problems in kinematic data collection. Single investigator helps to reduce variation from error of marker placement and all dogs should be similar breed, shape and size.

As a results of joint limitation motion due to surgical procedure, AROM exercise such as application of non-slipping socks may have an advantage to increase AROM. Especially, measuring of extensor activity, which implied in our results.

On the basis of results in this study, trotting exercise combination with wearing non-slipping socks was a therapeutic exercised in veterinary physical therapies in dogs. It can be combined with the other exercise and modality by therapist or owner without expensive tools and it can be home program. The investigation of our study serve as a basic guideline for future studies of AROM in Pomeranians with MPL.

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# APPENDIX

Control group

| Dog No. | Age (year) | Weight (kg) | Body condition score |
|---|---|---|---|
| 1 | 0.67 | 2.4 | 3.0 |
| 2 | 1.00 | 2.9 | 3.0 |
| 3 | 1.10 | 5.6 | 3.5 |
| 4 | 4.00 | 3.0 | 3.0 |
| 5 | 4.25 | 2.9 | 3.0 |
| 6 | 3.40 | 3.0 | 3.5 |
| 7 | 0.90 | 2.6 | 3.0 |
| 8 | 5.40 | 2.0 | 3.0 |
| 9 | 2.00 | 3.9 | 3.0 |
| 10 | 3.00 | 3.0 | 3.0 |
| a | 2.00 | 3.0 | 3.0 |
| b | 1..5 | 2.6 | 3.0 |



*Note: a and b are data of normal dogs.

Experimental group

| Dog No. | Age (year) | Weight (kg) | Body condition score |
|---|---|---|---|
| 11 | 6.30 | 4.1 | 3.0 |
| 12 | 0.67 | 2.2 | 3.0 |
| 13 | 1.30 | 4.0 | 3.5 |
| 14 | 0.80 | 3.2 | 3.0 |
| 15 | 1.30 | 3.2 | 3.0 |
| 16 | 2.00 | 4.8 | 3.0 |
| 17 | 4.70 | 3.0 | 3.0 |
| 18 | 1.30 | 2.0 | 3.0 |
| 19 | 1.00 | 2.5 | 3.0 |
| 20 | 1.00 | 2.5 | 3.0 |

| | Dog No. | Maximum extension angle | | | | | Maximum flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Sx | Week 2 | Week 4 | Week 6 | Week 8 | Before Sx | Week 2 | Week 4 | Week 6 | Week 8 | Before Sx | Week 2 | Week 4 | Week 6 | Week8 |
| Hip joint control group | 1 | 136.70 | 139.12 | 124.57 | 129.79 | 132.40 | 102.25 | 119.12 | 105.99 | 114.40 | 113.07 | 34.45 | 19.99 | 18.58 | 15.39 | 113.07 |
| | 2 | 140.59 | 143.85 | 138.96 | 115.77 | 138.79 | 120.59 | 118.58 | 106.35 | 93.68 | 110.78 | 20.00 | 25.28 | 32.61 | 22.09 | 110.78 |
| | 3 | 130.92 | 130.23 | 133.29 | 128.31 | 131.87 | 104.06 | 105.62 | 107.56 | 110.34 | 105.92 | 26.87 | 24.61 | 25.72 | 17.97 | 105.92 |
| | 4 | 134.86 | 134.51 | 140.63 | 139.56 | 130.86 | 107.68 | 106.23 | 112.88 | 108.26 | 101.04 | 27.18 | 28.27 | 27.74 | 31.30 | 101.04 |
| | 5 | 125.56 | 130.52 | 144.54 | 145.27 | 150.53 | 99.13 | 107.82 | 114.32 | 116.60 | 127.32 | 26.43 | 22.70 | 30.22 | 28.67 | 127.32 |
| | 6 | 134.40 | 123.15 | 125.43 | 133.57 | 123.03 | 112.15 | 105.81 | 106.88 | 110.54 | 101.95 | 17.25 | 17.35 | 18.55 | 23.03 | 101.95 |
| | 7 | 138.42 | 132.00 | 134.57 | 132.15 | 134.26 | 112.45 | 109.12 | 108.27 | 108.97 | 110.56 | 25.97 | 22.88 | 26.30 | 23.19 | 110.56 |
| | 8 | 134.49 | 133.34 | 134.57 | 132.06 | 134.54 | 108.33 | 110.33 | 108.89 | 108.97 | 110.09 | 25.36 | 23.03 | 25.57 | 23.08 | 110.09 |
| | 9 | 133.45 | 134.52 | 135.52 | 136.60 | 136.58 | 110.54 | 108.25 | 107.52 | 108.51 | 102.26 | 22.91 | 26.27 | 28.00 | 28.09 | 102.26 |
| | 10 | 129.45 | 129.45 | 131.15 | 132.25 | 134.26 | 104.45 | 103.46 | 103.11 | 104.45 | 105.69 | 25.00 | 25.99 | 28.04 | 27.80 | 105.69 |

| | Dog | Extension angle | | | | | Flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 |
| Stifle control group | 11 | 155.10 | 145.00 | 152.90 | 147.43 | 160.23 | 104.73 | 119.78 | 116.34 | 109.74 | 117.25 | 50.37 | 50.09 | 36.56 | 37.69 | 42.98 |
| | 12 | 160.27 | 150.00 | 162.25 | 162.26 | 165.84 | 114.60 | 116.66 | 107.88 | 100.28 | 116.48 | 45.67 | 51.15 | 54.37 | 61.98 | 49.36 |
| | 13 | 153.25 | 150.00 | 150.20 | 153.52 | 161.93 | 98.27 | 112.25 | 100.61 | 101.52 | 111.50 | 54.98 | 37.75 | 49.59 | 37.50 | 50.42 |
| | 14 | 159.03 | 156.56 | 160.47 | 158.60 | 169.20 | 98.97 | 95.37 | 106.07 | 105.53 | 101.12 | 60.05 | 61.20 | 54.40 | 53.07 | 68.08 |
| | 15 | 138.19 | 158.55 | 148.80 | 155.96 | 159.54 | 85.95 | 99.71 | 84.11 | 100.52 | 106.96 | 52.23 | 58.84 | 64.70 | 55.44 | 52.58 |
| | 16 | 152.72 | 140.84 | 140.68 | 160.52 | 148.73 | 104.26 | 97.77 | 91.91 | 100.23 | 97.78 | 48.45 | 43.07 | 36.77 | 60.29 | 50.94 |
| | 17 | 154.03 | 158.25 | 154.58 | 150.53 | 157.37 | 100.70 | 102.57 | 100.58 | 97.26 | 100.33 | 53.33 | 55.68 | 54.00 | 53.27 | 57.04 |
| | 18 | 153.22 | 151.32 | 152.84 | 155.55 | 160.40 | 101.07 | 106.30 | 101.07 | 102.15 | 107.35 | 51.96 | 50.35 | 49.40 | 53.39 | 52.39 |
| | 19 | 155.58 | 160.50 | 152.25 | 147.26 | 158.25 | 98.26 | 104.52 | 101.58 | 97.25 | 105.37 | 57.32 | 55.98 | 50.67 | 50.01 | 52.89 |
| | 20 | 152.52 | 158.24 | 156.75 | 155.32 | 162.27 | 102.60 | 103.52 | 102.58 | 100.37 | 103.27 | 49.93 | 54.72 | 54.17 | 54.96 | 59.00 |

| | Dog No. | Extension angle | | | | | Flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 |
| Hock joint control group | 1 | 155.10 | 145.00 | 152.90 | 147.43 | 160.23 | 104.73 | 119.78 | 116.34 | 109.74 | 117.25 | 50.37 | 50.09 | 36.56 | 37.69 | 42.98 |
| | 2 | 160.27 | 150.00 | 162.25 | 162.26 | 165.84 | 114.60 | 116.66 | 107.88 | 100.28 | 116.48 | 45.67 | 51.15 | 54.37 | 61.98 | 49.36 |
| | 3 | 153.25 | 150.00 | 150.20 | 153.52 | 161.93 | 98.27 | 112.25 | 100.61 | 101.52 | 111.50 | 54.98 | 37.75 | 49.59 | 37.50 | 50.42 |
| | 4 | 159.03 | 156.56 | 160.47 | 158.60 | 169.20 | 98.97 | 95.37 | 106.07 | 105.53 | 101.12 | 60.05 | 61.20 | 54.40 | 53.07 | 68.08 |
| | 5 | 138.19 | 158.55 | 148.80 | 155.96 | 159.54 | 85.95 | 99.71 | 84.11 | 100.52 | 106.96 | 52.23 | 58.84 | 64.70 | 55.44 | 52.58 |
| | 6 | 152.72 | 140.84 | 140.68 | 160.52 | 148.73 | 104.26 | 97.77 | 91.91 | 100.23 | 97.78 | 48.45 | 43.07 | 36.77 | 60.29 | 50.94 |
| | 7 | 154.03 | 158.25 | 154.58 | 150.53 | 157.37 | 100.70 | 102.57 | 100.58 | 97.26 | 100.33 | 53.33 | 55.68 | 54.00 | 53.27 | 57.04 |
| | 8 | 153.22 | 151.32 | 152.84 | 155.55 | 160.40 | 101.07 | 106.30 | 101.07 | 102.15 | 107.35 | 51.96 | 50.35 | 49.40 | 53.39 | 52.39 |
| | 9 | 155.58 | 160.50 | 152.25 | 147.26 | 158.25 | 98.26 | 104.52 | 101.58 | 97.25 | 105.37 | 57.32 | 55.98 | 50.67 | 50.01 | 52.89 |
| | 10 | 152.52 | 158.24 | 156.75 | 155.32 | 162.27 | 102.60 | 103.52 | 102.58 | 100.37 | 103.27 | 49.93 | 54.72 | 54.17 | 54.96 | 59.00 |

| | Dog No. | Maximum extension angle | | | | | Maximum flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 |
| Hip joint Ex A | 11 | 132.20 | 128.42 | 146.23 | 136.36 | 124.67 | 113.34 | 102.24 | 121.36 | 112.32 | 108.55 | 18.87 | 26.18 | 24.87 | 22.28 | 16.12 |
| | 12 | 124.17 | 138.09 | 138.95 | 131.10 | 137.82 | 95.85 | 113.10 | 112.96 | 106.39 | 111.24 | 28.32 | 25.00 | 25.99 | 24.71 | 26.58 |
| | 13 | 116.23 | 130.97 | 139.43 | 122.80 | 125.67 | 101.22 | 110.69 | 119.87 | 103.77 | 98.62 | 15.01 | 20.28 | 19.57 | 19.03 | 27.05 |
| | 14 | 128.59 | 135.49 | 124.03 | 124.60 | 123.27 | 111.00 | 116.60 | 107.07 | 107.17 | 104.27 | 17.59 | 18.89 | 16.96 | 17.42 | 19.00 |
| | 15 | 131.46 | 139.83 | 136.42 | 136.73 | 147.83 | 111.22 | 113.28 | 110.18 | 115.77 | 128.31 | 23.29 | 26.71 | 26.00 | 20.77 | 19.03 |
| | 16 | 144.11 | 147.02 | 166.54 | 143.00 | 145.86 | 122.42 | 129.39 | 143.99 | 123.44 | 122.38 | 21.69 | 17.63 | 22.55 | 19.56 | 23.49 |
| | 17 | 123.65 | 125.77 | 131.32 | 120.29 | 127.55 | 99.32 | 104.10 | 102.72 | 93.80 | 102.87 | 24.33 | 21.67 | 28.60 | 26.50 | 24.68 |
| | 18 | 112.52 | 127.79 | 130.21 | 133.58 | 133.27 | 97.08 | 109.04 | 106.54 | 112.48 | 110.26 | 15.44 | 18.76 | 23.67 | 21.11 | 23.01 |
| | 19 | 112.80 | 151.63 | 133.11 | 108.75 | 129.33 | 96.59 | 117.18 | 106.48 | 83.75 | 95.45 | 16.21 | 34.45 | 26.63 | 25.00 | 33.88 |
| | 20 | 159.05 | 147.86 | 136.82 | 146.37 | 151.34 | 138.85 | 127.75 | 117.50 | 129.70 | 129.77 | 20.20 | 20.10 | 19.33 | 16.67 | 21.57 |

| | Dog | Extension angle | | | | | Flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 |
| stifle joint EX A | 11 | 152.37 | 153.04 | 157.78 | 154.93 | 159.98 | 108.96 | 100.32 | 92.66 | 104.84 | 90.58 | 43.41 | 52.72 | 65.11 | 50.09 | 69.40 |
| | 12 | 148.48 | 141.85 | 162.60 | 163.00 | 157.94 | 103.66 | 113.18 | 120.27 | 107.04 | 104.64 | 44.82 | 28.66 | 42.33 | 55.96 | 53.30 |
| | 13 | 153.29 | 151.56 | 161.59 | 164.00 | 161.19 | 102.87 | 103.17 | 113.34 | 102.06 | 108.54 | 50.42 | 48.39 | 48.26 | 61.94 | 52.65 |
| | 14 | 156.85 | 149.41 | 160.06 | 165.00 | 169.56 | 107.14 | 95.60 | 108.78 | 97.94 | 105.28 | 49.71 | 53.81 | 51.28 | 67.06 | 64.28 |
| | 15 | 146.83 | 156.71 | 160.59 | 155.30 | 158.72 | 105.41 | 95.13 | 104.37 | 107.21 | 110.48 | 41.73 | 61.18 | 56.23 | 48.09 | 48.24 |
| | 16 | 162.41 | 158.01 | 178.79 | 160.61 | 155.13 | 102.95 | 114.45 | 129.36 | 110.85 | 103.04 | 59.46 | 43.56 | 49.43 | 49.76 | 52.09 |
| | 17 | 152.63 | 151.71 | 163.49 | 164.17 | 165.00 | 106.34 | 106.41 | 119.69 | 108.53 | 91.40 | 46.29 | 45.30 | 43.80 | 55.64 | 73.60 |
| | 18 | 160.73 | 157.68 | 163.48 | 162.00 | 162.22 | 102.80 | 112.89 | 112.11 | 104.71 | 110.00 | 57.92 | 45.19 | 51.37 | 57.29 | 52.22 |
| | 19 | 147.47 | 150.31 | 153.01 | 160.00 | 165.89 | 99.85 | 99.95 | 95.63 | 91.28 | 85.27 | 47.62 | 50.36 | 57.37 | 68.72 | 80.62 |
| | 20 | 146.21 | 164.14 | 149.73 | 161.45 | 167.87 | 95.34 | 97.11 | 99.56 | 113.18 | 90.86 | 50.87 | 67.03 | 50.17 | 48.27 | 77.01 |

| | Dog No. | Maximum extension angle | | | | | Maximum flexion angle | | | | | Range of motion | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 | Before Sx | Week2 | Week4 | Week6 | Week8 |
| Hock joint Ex A | 11 | 176.99 | 177.87 | 179.03 | 176.66 | 149.59 | 147.35 | 143.04 | 129.22 | 135.34 | 99.26 | 29.63 | 34.83 | 49.81 | 41.33 | 50.33 |
| | 12 | 154.22 | 172.79 | 174.37 | 176.14 | 164.92 | 119.27 | 137.65 | 138.27 | 140.39 | 119.71 | 34.96 | 35.14 | 36.10 | 35.76 | 45.21 |
| | 13 | 178.96 | 165.34 | 178.57 | 163.10 | 178.76 | 143.24 | 121.91 | 142.69 | 118.61 | 142.71 | 35.72 | 43.44 | 35.88 | 44.49 | 36.05 |
| | 14 | 169.92 | 179.24 | 179.17 | 169.63 | 178.26 | 129.11 | 144.82 | 159.14 | 131.76 | 140.27 | 40.80 | 34.42 | 20.03 | 37.86 | 38.00 |
| | 15 | 168.40 | 177.87 | 178.98 | 172.58 | 178.65 | 131.69 | 120.91 | 142.64 | 135.23 | 144.98 | 38.71 | 52.10 | 36.33 | 38.24 | 35.09 |
| | 16 | 170.70 | 168.04 | 177.79 | 173.13 | 166.48 | 124.33 | 124.73 | 143.71 | 142.82 | 125.47 | 46.37 | 43.30 | 34.08 | 30.31 | 41.01 |
| | 17 | 171.02 | 168.18 | 178.87 | 179.19 | 177.44 | 127.45 | 129.23 | 133.06 | 141.91 | 134.89 | 43.58 | 38.95 | 45.81 | 37.28 | 42.55 |
| | 18 | 165.75 | 165.08 | 169.56 | 164.32 | 165.77 | 131.62 | 139.52 | 135.66 | 127.69 | 130.45 | 34.13 | 25.56 | 33.90 | 36.63 | 35.32 |
| | 19 | 147.91 | 143.27 | 145.42 | 152.75 | 156.27 | 113.90 | 104.57 | 107.56 | 106.85 | 105.27 | 34.01 | 38.70 | 37.86 | 45.90 | 51.00 |
| | 20 | 177.86 | 178.70 | 174.36 | 176.68 | 166.03 | 120.89 | 139.15 | 134.11 | 148.79 | 116.82 | 56.97 | 39.55 | 40.26 | 27.90 | 49.22 |

Normal dogs

| | Dog No. | Maximum extension angle | Maximum flexion angle | Range of motion |
|---|---|---|---|---|
| Stifle joint | 21 | 170.682 | 106.747 | 63.9353 |
| | 22 | 172.545 | 111.861 | 60.6839 |
| | 23 | 159.626 | 106.302 | 53.3239 |
| | 24 | 161.052 | 104.99 | 56.0625 |

# VITA

Miss Wipa temkhunnatham was born on December 18th, 1987 in Bangkok, Thailand. She received her bachelor degree of Doctor of Veterinary Medicine (D.V.M.) from the Faculty of Veterinary Science, Chulalongkorn University in 2012. After graduation, she had spent a year as a clinician in a private small animal hospital. In 2014, she entered the Master Degree Program in Veterinary Surgery of Chulalongkorn University.