A Doctoral Dissertation

Wii Balance Board for the Diagnostic and Prognostic Assessment in the Dog with Medial Patellar Luxation

GRADUATE SCHOOL
JEJU NATIONAL UNIVERSITY

College of Veterinary Medicine

Shinho Lee

Feb, 2019

Wii Balance Board for the Diagnostic and Prognostic Assessment in the Dog with Medial Patellar Luxation

Shinho Lee
(Supervised by Professor Jongtae Cheong)

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in veterinary medicine

2018. 12.

This thesis has been examined and approved by

Thesis director, Joo-Myoung Lee, Prof. of Dept. of Veterinary Medicine

---

Tae-Young Kang, Prof. of Dept. of Veterinary Medicine

Gonhyung Kim, Prof. of Dept. of Veterinary Medicine

Jong-pil Seo, Prof. Dept. of Veterinary Medicine

Jongtae Cheong, Prof. of Dept. of Veterinary Medicine

....
Date

College of Veterinary Medicine

GRADUATE SCHOOL

JEJU NATIONAL UNIVERSITY

CONTENTS

CHAPTER II

Validity of the Wii Balance Board for Evaluation of Medial Patellar Luxation in Small Sized Dog

CHAPTER Ⅲ

Balance Evaluation after Reconstruction of Medial Patellar Luxation in Small Sized Dog with Wii Balance Board

Wii Balance Board for the Diagnostic and Prognostic Assessment in the Dog with Medial Patellar Luxation

Shinho Lee
(Supervised by professor Jongtae Cheong)

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of science in veterinary medicine

Abstract

Wii® balance board (WBB) is a device that can measure and record body sway. This study was conducted to evaluate reliability of WBB in small sized dog as inexpensive, portable and convenient tool. The center of pressure path length (CPPL) and 95% confidence ellipse area (Area 95) were evaluated with only two plates of WBB. Whether the internally stored calibration values were significant values demonstrated between no load and mass group. The parameters were evaluated between no load (0 kg) and mass group (0.25~4 kg on each one plate). And 23 dogs (2.3~7.3 ㎏) were evaluated for with hindlimb standing for 10 seconds. The average of CPPL and Area 95 was 13.4 ± 0.77 m, 22.6 ± 7.55 ㎠ in no load for 10 seconds, respectively. The mass group showed a significant values in comparison to the no load during the measurement (p <0.01). And intra-class correlation coefficients (ICCs) (=0.91) between CPPL and Area 95

revealed very high. The average of CPPL and Area 95 was 2.9 ± 0.81 m, 2.0 ± 0.71 ㎠, respectively in dogs. Group of dogs revealed high ICCs (= 0.86) between CPPL and Area 95. In the evaluation of medial patellar luxation (MPL) as a diagnostic tool, 80 dogs with MPL and 23 intact dogs were participated in this study. Significant differences of CPPL were found between non-affected and grade Ⅲ MPL group (p <0.01). Significant differences of Area 95 were found between non-affected stifles and grade Ⅲ, Ⅳ group (p <0.01). Significant differences of CPPL were found between non-affected and grade Ⅲ (p < 0.01), Ⅳ group (p <0.01). Significant differences of Area 95 were found among non-affected and grade Ⅱ (p <0.05), Ⅲ (p < 0.01), Ⅳ group (p <0.01). For evaluating measure of improvement after reconstruction of MPL in small sized dogs, 6 dogs with MPL were participated in this study. Dogs were measured for difference of extension and flexion range of motion in the stifle (dROM), muscle mass, lameness, willingness to bear weight on the affected limb while standing, and willingness to lift the contralateral limb scores, CPPL and Area 95 of WBB on pre-surgery, post-surgery 4, 8 weeks. dROM, muscle mass, lameness score, willingness to bear weight on the affected limb while standing, willingness to lift the contralateral limb scores, and Area 95 was significantly different on pre-surgery compared with post-surgery 4 and 8 weeks (p < 0.01). CPPL was significantly different on pre-surgery compared with post-surgery 8 weeks (p < 0.05).

As results, WBB can be a valid and reliable tool for the diagnostic and

prognostic assessment in small sized dog with MPL.

Key words: Wii balance board (WBB), body sway, center of pressure path length (CPPL), 95% confidence ellipse area (Area 95), dog

List of Abbreviations

Area 95	95% confidence ellipse area
COP	Center of pressure
CPPL	Center of pressure path length
dROM	Difference of extension and flexion range of motion in the stifle
MPL	Medial patellar luxation
OA	Osteoarthritis
ROM	Range of motion
WBB	Wii balance board

List of Figures

List of Tables

GENERAL INTRODUCTION

A basic body posture is maintained with dorsal side up in quadrupeds due to the activity of the postural control system (Beloozerova *et al.*, 2003). Postural sway is defined as constant compensatory movements. The continuous movement of the body's center of mass can be measured through detecting fluctuations of the center of pressure (COP) (Bekkers *et al.*, 2014; Manera *et al.*, 2017). Balance requires a complex interplay of somatosensory (70%), visual (10%) and vestibular (20%) system to maintain a stable upright stance (Horak, 2006). The center of pressure path length (CPPL) is a sum of distance in the location where all the vertical force acts (Park and Lee, 2014). Area 95 means 95% confidence ellipse area (Brichetto *et al.,* 2013). CPPL and Area 95 have been shown to be effective parameters to monitor body sway (Harris *et al.,* 1993). Balance is the basic element of all active daily living, and evaluation of balance has been conducted to measure postural sway of center of pressure (COP). Static standing COP measures may be used as a good reliability and validity for assessment of static standing balance and weight-bearing asymmetry in human adults for the analysis of postural control sway (Clark *et al.*, 2010; Clark *et al.*, 2011).

The WBB is a 23×43 cm platform that wirelessly transmits vertical forces using Bluetooth program from under each corner as a user stands on its surface (Bartlett *et al.,* 2014). The WBB has generated significant interest in the human neurorehabilitation research domain and the system is relatively inexpensive, easy to access and portable (Goble *et al*., 2014). A few studies have used custom software to interface a computer to the WBB to measure Area 95 and CPPL (Clark *et al*., 2011; Park and Lee, 2014). WBB are becoming common tool to both measure inter-limb force symmetry and provide feedback to patients about inter-limb force symmetry in human rehabilitation (Abujaber *et al.,* 2015). Both WBB and force plate have satisfactory reproducibility and validity for bipedal and unipedal static balance tests in a child population (Larsen *et al.,* 2014).

Knee osteoarthritis (OA) is characterized by degenerative destruction of articular cartilage, meniscal tears and degeneration, and changes in ligament integrity and accompanied by pain (Lohmander *et al.,* 2007). Knee OA in human is a degenerative joint disorder characterized primarily by cartilage, bone, ligament and synovial tissue changes, which lead to pain and a reduction in the flexibility of the joint (Crook *et al.,* 2007; Wiegant *et al*., 2015). When hyaline cartilage damage occurs, it affected secondary meniscus damage, stifle OA, and synovial inflammation in dog model (Frost-Christensen *et al.,* 2008). Patellar luxation describes a condition where the patella can slip from its normal groove at the distal of the femur (O'Neill *et al.,* 2016). The dog patellar luxation is important orthopeadic disorders over half century and has been recognized for joint deformity (Piermattei *et al.,* 2006; O'Neill *et al.,* 2016). The disease of patellar luxation is progressive stifle OA from the patella and medial trochlear ridge, increased risk of cranial cruciate ligament rupture, and diminished strength of the quadriceps muscles due to displacement of the growth phase (Roy *et al.,* 1992; Gallegos *et al.,* 2016).

In previous study to compare the trotting gait of normal and lame dogs using multiple ground reaction forces, dogs with OA at the stifle have a more severe decrease than dogs with OA of hip joint disease (Madore *et al.,* 2007). If the asymmetry is subtle, it is difficult to diagnose the affected sided limb by watching a dog walk (Garcia *et al.*, 2017). As the gold standard for assessing osteoarthritis in dogs, force plate allows neuromuscular and skeletal disorders to be evaluated (Rialland *et al.*, 2012). However, in smaller dogs and cats comparing to large quadrupeds (>20kg), the presence of more than a paw in contact with the force platform compromises the measurement by a summation process (Moreau *et al.,* 2014).

There is few modalities for assessing body sway of the dog in animal clinics, and mostly were adapted from human rehabilitation. Thus, there is a need for portable, economical device and valid measurement of sway performance especially in clinical research. Since there is not enough information on the reliability and validity of parameters using WBB in small animals, it is necessary to evaluate the suitability of the device for measuring the balance evaluation. The purpose of this study was to identify whether the WBB is suitable for balance of dog and evaluate WBB as useful diagnostic and prognostic tool in small sized dog with MPL

CHAPTER Ⅰ

Evaluation of Hindlimb Balance in the Dog using Wii Balance Board

I - 1. Introduction

The balance is an ability to maintain vertical line from center of mass of a body within the base of support (Shumway-Cook *et al.,* 1988; Gillette and Graig, 2014). The sway is the horizontal movement of the center of gravity when a person is standing still. The COP is a coordinate of the center of gravity within the surface of any parts of the body which are in contact with the ground (Clark *et al.,* 2018). The continuous movement of the body's center of mass can be measured through detecting fluctuations of the COP (Manera *et al.,* 2017; Bekkers *et al.,* 2014). The maintenance of posture requires an integration of vestibular, visual and somatosensory inputs in the quadrupedal animal. The vestibular system is important to maintain the stability of the thoracic limb and the orientation of the head, and somatosensory information is relatively important to maintain the limb stability of the trunk and pelvis (Beloozerova *et al.*, 2003; Hamilton *et al.,* 2008).

The WBB was released in 2007 to combine fun and fitness for all ages, as exercise-based game software for the Nintendo Wii® system, which has been a popular modality and combined with therapy interventions (Clark *et al.,* 2018; Mhatre *et al.*, 2013; Tripette *et al.,* 2017). It is the platform that tracks changes in the COP during exercise games and wirelessly transmits vertical ground reaction forces when subject move on the board. Even the measured data are not directly accessible to the researcher, previous study has used custom software to interface a computer to the WBB to measure the data including CPPL and Area 95 (Park and Lee, 2014).

The WBB can be used as a reliable and valid tool for assessing standing balance comparing with force plate (Huurnink *et al.,* 2013; Larsen *et al.,* 2014; Clark et al., 2018). In previous study, weight bearing asymmetry was prevalent in wide range clinical populations. For example, asymmetry was common in human stroke patients. The greater load distributed to the less impaired limb has been associated with an increase in postural sway (Genthon *et al.*, 2008). However, in smaller dogs and cats comparing with large quadrupeds (>20kg), the presence of more than a paw in contact with the force platform makes it difficult to measure by a summation process (Moreau *et al.,* 2014). The WBB is adequate as a substituent for the initial force platform since it is affordable and easy to carry around (Goble *et al.,* 2014).

The tools for assessing body sway of the dog were not sufficient in small animal clinics. Thus, there is a need for transportable, low-cost device, and reliable measurement of sway performance especially in both veterinary laboratory and field settings.

Since there is not enough information on the benefits of the reliability and usefulness of parameters using WBB in the application of small animals, it is necessary to evaluate the suitability of the device for measuring the balance control. The purpose of this study was to provide the basic data for static loads provided with calibrated data to allow researchers to evaluate whether the WBB is suitable for balance of small sized dog. This study is a pilot to evaluate WBB using program for evaluating balance ability as a diagnostic tool in veterinary medicine.

Ⅰ - 2. Materials and Methods

WBB description, data interface: The WBB (Nintendo, Japan) consists of similar componentry including four load cell transducers at the corners of the board, one transducer per foot of the board edge (Figure 1). Each transducer is a load cell consisting of a cantilevered metal bar with load sensors that relay the coordinates of the user's position in the form of the COP. Sensor values from bar with a strain gauge-based were reported as 4 channels of un-calibrated 16-bit digital data sampled at approximately 100 Hz wirelessly. The customized software (Balancia® v2.0, Minto systems, Korea) was used together, which was connected wirelessly to a laptop computer via Bluetooth and communicated to obtain CPPL and Area 95.

Figure 1. The WBB coordinate system and force transducers. (A) The x and y coordinates of the pressure center on the WBB are recorded for each frame. B) Foot−pegs housing force sensors (circle) are found under each of the four corners of the board as a uni−axial force transducer.

Method of force application: Accuracy of the COP calculations for the WBB were performed with vertical forces of the four load sensors, and the distance between a load sensor and the middle of the WBB in the x (anteroposterior) and y (mediolateral) direction, respectively. In this study, the COP calculation was tested for two load cell by placing different mass levels at specific spatial locations across the top surface of the device. The Balancia® software program was used to obtain the data for WBB and the acquired values were calculated as follow:

Path length is the path length for the duration of the trial.

$$l_{path} = \Sigma \sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}$$

Area 95 means the sway area (㎠) including 95% confidence ellipse of the dispersion of COP positions (Brichetto *et al.,* 2013).

For testing WBB, no load (0 ㎏) and 16 separate masses spanning the range of 0.25~4 ㎏ were tested. It was assessed by adding 0.25 ㎏ from 0.25g to 4kg. Each mass was centered and data were collected from only two plate channels via Balancia® at 100 Hz for 10 seconds (Figure 2). Masses used on the WBB were selected for detailed measurement. The procedure was applied three times at same locations distributed across the surface of the WBB to each plate board using different mass levels. Only two plates were used in this study. Data were recorded for 10 seconds at each mass level, which were incremented in decreasing then increasing order. Examiner lifted masses into the air while the WBB were reset between each test.

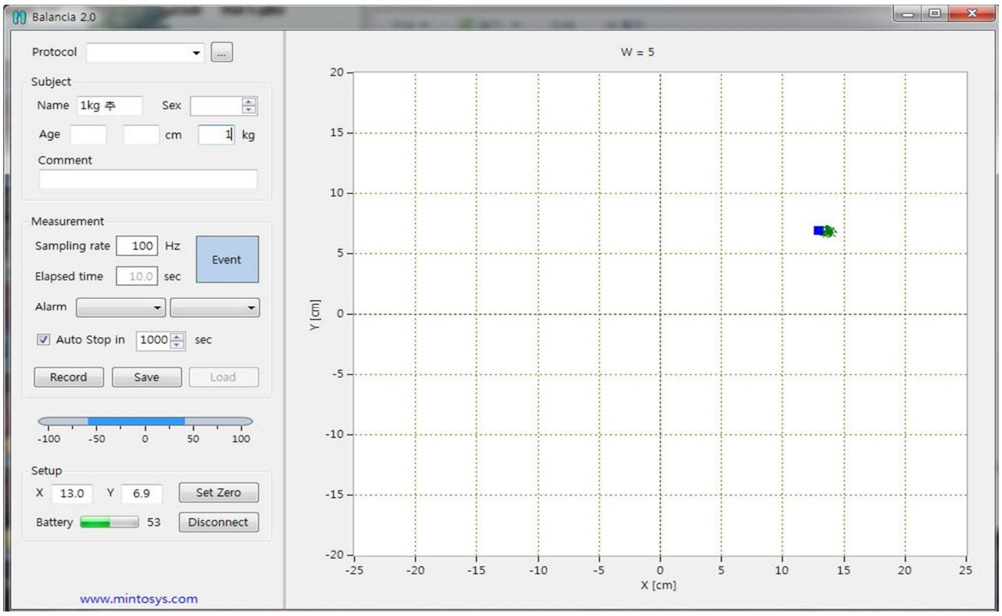

Figure 2. Balancia® software user interface. A user can connect the WBB and Balancia® software in a laptop equipped with Bluetooth for signal acquisition and analysis. Data were transmitted from the WBB to the laptop using the built-in Bluetooth and Balancia® software.

Application for dog: A total of 23 intact dogs were included (2.3~7.3 ㎏) with quiet hindlimb standing for 10 seconds. The technician held the dog from the front in a straight, bipedal standing position, and was instructed not to provide any manual support for the dog. The hindlimb were allowed to weigh as full as possible. Each paw of hindlimb was centered on each force plate. The dogs were positioned with an angle of 30~40 degrees. The angle was determined by the horizontal plane and the line joining the dorsal aspect of scapular spine and greater trochanter (Figure 3). Ventrodorsal and lateral standard radiographic views of stifle and hip joints were taken from dogs belonging to experiment group to confirm or rule out other orthopedic disease. Dogs performed three repetitions of hindlimb standing on WBB for 10 seconds. 10 seconds break time was allowed between each experimental trial on the WBB. In case of behavioural problems, the examiner lifted the whole body into the air while the WBB was reset.

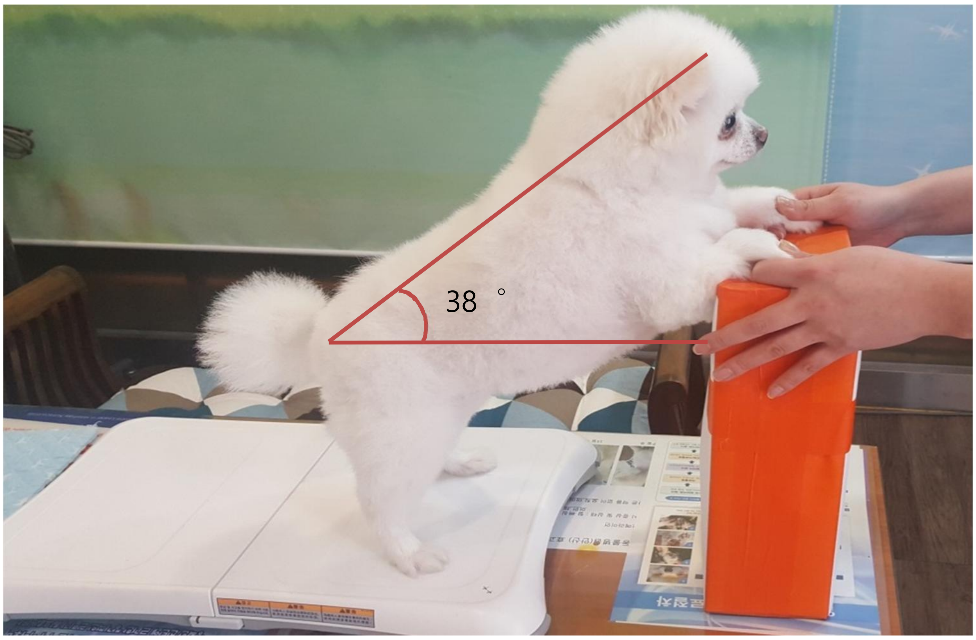

Figure 3. A dog posture on the WBB. A dog performed static posture while a force from each foot on the WBB transmitted.

Statistical Analysis: All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Inc. Version 19.0, Chicago, IL, USA). The three repetitions of each testing condition were used to describe relative reliability. Data was presented as means ± SD. A student's t-test was used for statistical analysis. Differences were seemed to be statistically significant when $p < 0.05$ between no load and mass group. An intraclass correlation coefficient (ICC) between 0.75 and 1 was considered high, 0.4-0.74 modest and less than 0.39 low (Clark *et al.*, 2010). Each ICC was calculated for CPPL and Area 95 in both different mass and intact dog group study. In addition, scatter plots were created.

Ⅰ - 3. Results

When an animal is moving, the distribution of the vertical force within the paw is modified and the COP changes accordingly. The COP can also be depicted as a trajectory according to its displacement during the stance phase.

Internal calibration has done by evaluating the COP between no load and mass group on the only two WBB load sensors. The each average of CPPL and Area 95 was 13.4 ± 0.77 m, 22.6 ± 7.55 ㎠ in no load. A statistical significance in CPPL and Area 95 was found between no load and mass group (p <0.01). Data was presented as means ± SD. A student's t-test was used for statistical analysis between no load and mass group. Each description of no load and mass group in CPPL and Area 95 is summarized (Table 1). ICC (=0.91) value was shown to be consistently excellent between CPPL and Area 95 from scatter plots (Figure 4).

The subjects used in this study were 23 small sized dogs without neurologic and orthopedic sign. There were 8 males and 15 females, 7 were castrated and 5 were spayed. The body weight of enrolled dogs ranged from 4.7 ± 1.6 kg, and ages were 3.0 ± 2.2 years. The each average of CPPL and Area 95 was 2.9 ± 0.81 m, 2.0 ± 0.71 ㎠. ICC value (=0.86) were found to be statistically significant (Figure 5).

Table 1. Comparison of CPPL and Area 95 between no load and mass groups

Mass	Number	CPPL(m)	Area 95 (㎠)
0 g	3	13.4 ± 0.77	22.6 ± 7.60
250 g	3	8.1 ± 1.06**	13.6 ± 10.39**
500 g	3	5.5 ± 0.18**	4.0 ± 0.12**
750 g	3	4.2 ± 0.12**	2.4 ± 0.14**
1000 g	3	2.5 ± 0.12**	0.9 ± 0.10**
1250 g	3	2.3 ± 0.04**	0.8 ± 0.19**
1500 g	3	2.1 ± 0.01**	0.6 ± 0.02**
1750 g	3	1.9 ± 0.04**	0.5 ± 0.04**
2000 g	3	1.8 ± 0.02**	0.4 ± 0.02**
2250 g	3	1.5 ± 0.01**	0.3 ± 0.01**
2500 g	3	1.3 ± 0.04**	0.3 ± 0.01**
2750 g	3	1.3 ± 0.05**	0.2 ± 0.00**
3000 g	3	1.1 ± 0.04**	0.2 ± 0.00**
3250 g	3	1.1 ± 0.03**	0.2 ± 0.00**
3500 g	3	1.1 ± 0.08**	0.2 ± 0.00**
3750 g	3	1.0 ± 0.03**	0.1 ± 0.00**
4000 g	3	0.9 ± 0.01**	0.1 ± 0.00**

Variable: Mean±SD, **: $p < 0.01$

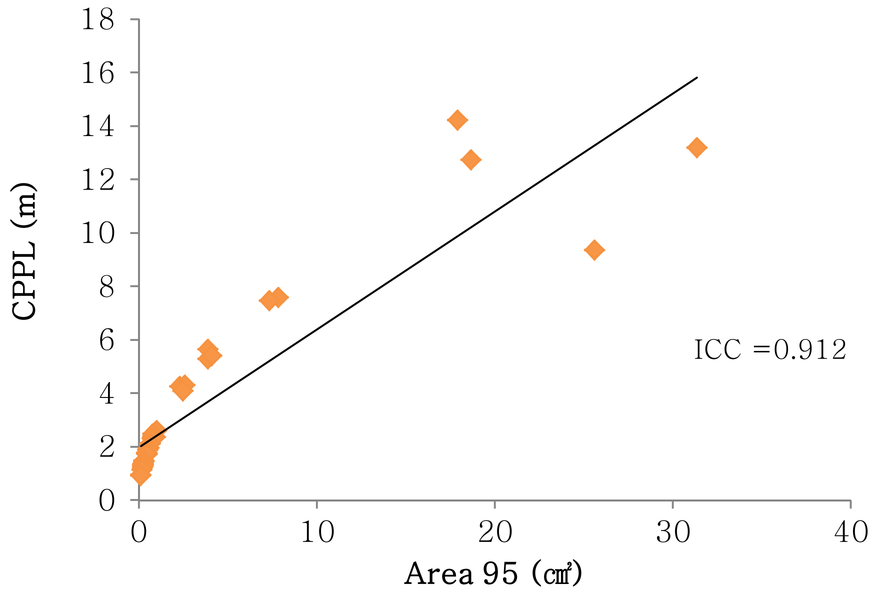

Figure 4. Scatter plot illustrating the relationship between CPPL and Area 95 using WBB in no load and mass group. The reliability of outcome measure was shown very high.

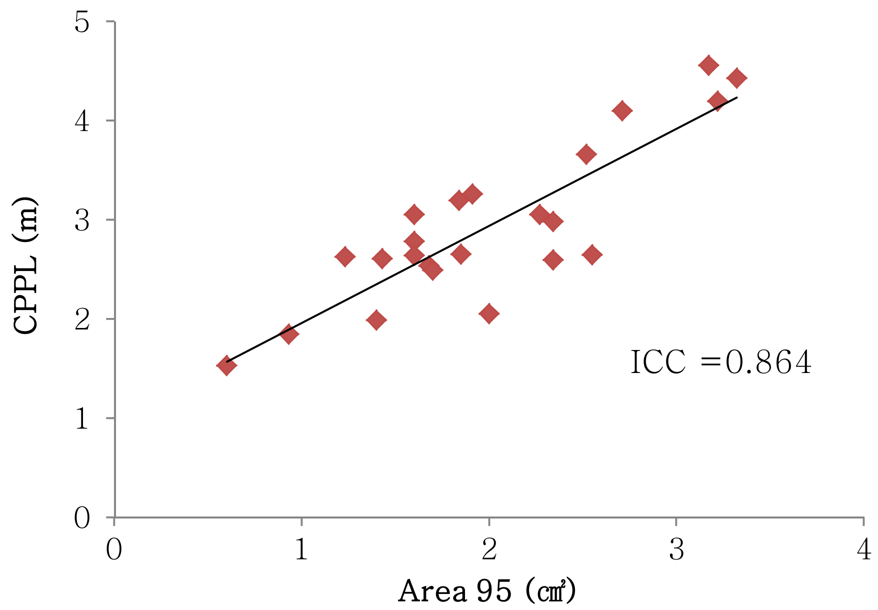

Figure 5. Scatter plot illustrating the relationship between CPPL and Area 95 using WBB in dogs group. The reliability of outcome measure was shown very high.

I - 4. Discussion

The WBB load cell like a bathroom scale shifts in weight via four strain gauge sensors at the corners of the board through vertical force (Pagnacco *et al.,* 2011). In dogs with hindlimb osteoarthritis, bathroom scale can be used as reliable, objective method by measuring of symmetry of the static weight bearing (Hyytiainen *et al.,* 2012). With this similarity in WBB, the CPPL and Area 95 can also be deviated as a trajectory according to its displacement during hindlimb standing. Using WBB was able to measure the distance and area of weight shift and sample them conveniently rather than using a scale.

As previously published in humans, the WBB is sufficiently accurate for quantifying CPPL trajectory and overall amplitude during single- leg stance balance tasks (Huurnink *et al.*, 2013). This study showed that two plates of were used to investigate correlation in a set of parameters among sound dogs' hindlimbs with standing on the WBB. The WBB was capable of obtaining information about animal's balance capabilities using a novel method. The force measurements were investigated by measuring the asymmetrical weight bearing and body sway to applying the WBB in small sized dog.

For a dog standing still on 4 limbs, the body weight is expected to be supported at 30% by each thoracic limb and at 20% by each pelvic limb (Foss *et al.,* 2013). The center of mass in dog is closer to the forelimbs during standing. For this reason, the center of mass contributes to this imbalance in hindlimb to forelimb weight distribution when standing (Gillette and Graig, 2014; Moreau *et al*., 2014). This study was carried out by selecting two of the four plates on the WBB to load weight on the forelimb or hindlimb in small animals. In order to clarify the orthopedic problems of quadruped animals, this study was designed to allow the load to be concentrated in the only two hindlimbs. Considering this is the actual load proportional to the weight bearing of the dog affecting the critical results, only two load cells are used in this study. The environment that can affect the experiment was performed in a relaxed and quiet atmosphere.

Horizontal force during standing balance is very small in the range from 0 to 7N, representing at most 1.25% of vertical force. The COP may be almost neglected in the horizontal force of WBB in older humans (Scaglioni-Solano *et al.,* 2014). Compared with humans, horizontal forces in small dogs are considered to be much lower. The horizontal force component was not considered in this study.

In previous study, the COP has been shown that trial lengths of 30s or more with data collected during 100 Hz and the number of repeated trials of at least five or more provide reliable results. It was concluded that 30s or more produced better results than 10s trials (Doyle *et al.,* 2007). However, acquisition time was established at 10 seconds in this study. Because the masses were non-mobile objects, and the dogs showed a decrease in concentration and fatigue when it exceeded 10 seconds, this study was conducted for 10 seconds.

The sampling frequency in humans suggests to consider an effective sampling rate of about 50 Hz whereas considering that canine body sway is a pendular movement, the pendulous length is shorter in dogs than in humans. To gain accurate canine postural sway, the frequency should be 100 Hz (Bottaro *et al.,* 2005; Manera *et al.*, 2017). This study used the dogs of different conformation. There may be variation in standard deviation due to the difference of each individual vertical distance on the WBB in center of gravity. For that reason, the sampling rate was applied to 100 Hz in order to gain accuracy in detail. As a result, the similar correlation was shown even when applying various different breed dogs.

Almost other studies have focused on investigating differences in the WBB for CPPL (Clark *et al.,* 2018). This study presented results on two parameters (CPPL and Area 95) derived from COP. The Area 95 compared with CPPL confirmed the change in the excursion range of body sway by confirming the area of the patient's movements, thus predicting the affected sided where clinical symptoms may be present, or identifying non-visible impairments.

In previous study, the detailed force protocol was applied 5 times to each sensor using 20 different mass levels on the WBB (no load~29.3 kg) for each sensor using a custom weight-applicator (Bartlett *et al.,* 2014). In this study, dogs' hindlimb and 17 different masses were also placed in quiet stance on the WBB, perpendicularly because it is necessary to confirm the validity that can be directly applied to the clinical practice. As comparison of CPPL between no load and mass group, the WBB was able to detect the movement and excursion of objects through the CPPL trajectory, and it showed significant differences between no load (0 kg) and mass group (0.25 ~ 4 kg).

Previous studies on an asymmetric oscillation in large breed with forelimb OA showed significant differences were found between sound and lame limbs (Manera *et al., 2017*). This study showed the similar result by recording CPPL and Area 95 in scatter plots. When compared with the results of figure 4, the ICC point for concurrent validity are noticeably similar in figure 5 (ICCs =0.91 versus ICCs =0.86). The findings in the present study of excellent ICCs for CPPL and Area 95 data recorded using inexpensive and portable WBB could be of great clinical and research utility. There was no data in small sized dogs. Basic data were established through ICCs in the intact small sized dogs and mass group. It could assume that significant results would be also obtained in dogs with orthopedic or neurological impairment.

There were several limitations to this study. Dogs with lack of concentration, severe panting and abnormal behavioural problem were excluded in this study. It was absolutely necessary to enroll calm and obedient dogs with quiet standing for the test time required to obtain valid COP. This study did not use dogs of similar conformation and used a relative low number of animals.

The WBB that is small in size, light in weight and relatively cheap showed to have good validity and reliability. This study is a pilot study to investigate the feasibility of diagnosis and prognosis in small animal clinics.

CHAPTER Ⅱ

Validity of the Wii Balance Board for Evaluation of Medial Patellar Luxation in Small Sized Dog

Ⅱ - 1. Introduction

The MPL which causes progressive pain, cartilage wear, lameness and OA due to a malalignment of the quadriceps muscle is one of the most common orthopedic conditions in small animal practice (Harasen, 2006b; Alam *et al.,* 2011). Developmental MPL is a common disease especially in toy dogs and other small breeds including Pomeranian, Chihuahua, Boston terrier, poodle, and Yorkshire terrier (Harasen, 2006a). It has been reported that MPL increases the stress on the musculoskeletal system, predisposing the structure to deformity of stifle joint and cranial cruciate ligament rupture. Secondary OA is a common result of MPL (Mortari *et al.,* 2009; Alam *et al.*, 2011).

The correct balance is an important process connected with the central nervous system, sight, and muscular system to keep the COP on the base of surface of the body (Ruhe *et al.,* 2010). Postural sway is being constantly perturbed by internal and external mechanisms and performed by constant compensatory movement (Manera *et al.*, 2017). When lameness is present, the associated pain causes instability in the static position and is provoked by the patient transferring weight from the affected sided limb to the non-affected sided limb (or less lame) in compensatory mechanism to alleviate the pain and not to fall down (Buchner *et al.,* 2001). In a dog with orthopedic disease, evaluation of the gait is first diagnostic step. If the asymmetry is subtle, it is not easy to diagnose the limited limb by watching a dog walk (Garcia *et al.*, 2017).

In kinetic gait analysis by force plates, dogs with abnormalities showed subtle changes in gait and lameness or limited limb function in activity daily living (Aristizabal *et al.,* 2017). A force plate can evaluate the functional impairment through the use of a pressure plate that monitors dog movements for ground reaction forces which measures the peak vertical force and vertical impulse to quantitatively assess the degree of lameness (Sharkey, 2013; Vilar *et al.*, 2016). In previous study to compare the trotting gait of normal and lame dogs secondary to stifle or hip OA using multiple ground reaction forces, dogs with OA at the stifle have a more severe decrease than those having OA of hip joint disease (Madore *et al.,* 2007). The advantage of this method is that consecutive, objective and non-invasive measurement of steps can be recorded. However, there is a lack research published on static analysis in lame dogs with postural changes, such as spatial modifications in body COP (Manera *et al.*, 2017).

The WBB is a clinically accessible, inexpensive and portable tool that is functionally similar to a force plate, and utilizes COP as a parameter of balance assessment in people with nervous system disorder (Bower *et al.,* 2014). Static COP measures may be used as a good reliability for assessment of static standing balance and weight-bearing asymmetry in healthy adults (Clark *et al.*, 2010; Clark *et al.,* 2011). Static bipedal standing becomes an objective evaluation method of the balance system, and it is widely used in human medicine, rehabilitation as the gold standard measurement for the analysis of postural control (Bonnechere *et al.,* 2015; Reguera−Garcia *et al.,* 2017).

This study was conducted to assess whether the WBB was valuable as an objective tool for diagnosing MPL,

Ⅱ - 2. Materials and Methods

Animals: A total of 103 dogs (66 males and 37 females) were examined. 80 dogs with MPL were diagnosed in animal hospital after orthopedic and radiological examinations. 23 dogs were intact. The breed, sex, age, and body weight of the dogs were recorded. According to the grade of patellar luxation, each stifle was assigned to a specific group according to Singleton's classification (Table 2).

Some of the patients were asymptomatic, and some had various degrees of unilateral or bilateral lameness, sometimes difficulty and reluctance to walk, jump and go upstairs. If the dog with bilateral MPL had the same grade, this study included only one as same grade. If the dog with MPL had different grade, the only higher grade was included. The animals were excluded from this study if they had any previous orthopedic disorder, including bone fracture, hip dysplasia, hip luxation and cranial cruciate ligament rupture. Dogs did not receive medication of any kind over the 2 weeks before the evaluation.

Table 2. Grading System for Medial Patellar Luxation (Singleton, 1969)

Grade Ⅰ	The patella is positioned normally but can be luxated with slight manual pressure.
Grade Ⅱ	Spontaneous luxation occurs; however, it can reduce spontaneously or can be replaced manually
Grade Ⅲ	The patella is luxated most of the time; however it can be replaced manually
Grade Ⅳ	The patella cannot be reduced manually

Static balance assessment: CPPL and Area 95 with WBB (Nintendo, Japan) were streamed using Bluetooth to a laptop computer and into software Balancia® (v2.0, Minto systems, Korea) at 100 Hz. The technician held the dog from the front in a straight, bipedal hindlimb standing position, and was instructed not to provide any manual support for the dog. Each paw of hindlimb was centered on each force plate. Each three recordings of 10 and 30 seconds were obtained from dogs. 10 second interval was allowed between each experimental trial. The mean values were calculated for each dog and were later used in the statistical analyses. Recorded values were rounded off to the second decimal place. The dog with higher grade MPL began to move. The dog maintained asymmetrical position and shifted weight bearing. Simultaneously, trajectory point was moved away (Figure 6). If the dog either stepped off from the plates during experiment, the examiner lifted the whole body into the air while the WBB were reset.

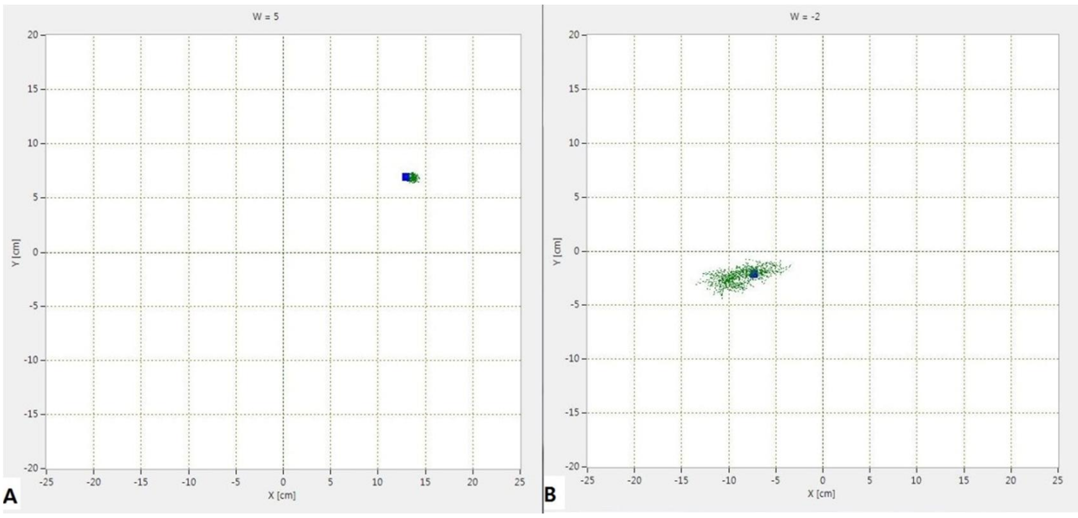

Figure 6. Trajectory for CPPL on the WBB. (A) If there is no deficit, the location of the COP in static testing would have very little excursion (i.e., a very short squiggly line) during the prescribed test period. (B) A dog with balance impairment would have a more extensive back−and−forth squiggly line, like scribbling and the COP is continually moving away.

Statistical Analysis: All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Inc. Version 19.0, Chicago, IL, USA). The three repetitions of each testing condition were used to describe relative reliability. Data were presented as means ± SD. A student's t−test was used for statistical analysis. Differences were seemed to be statistically significant when p <0.05 between non−affected stifle and affected stifle group.

Ⅱ - 3. Results

A total of 103 small sized dogs were used in this study. The body weight of enrolled dogs ranged from 2.0 to 7.5 kg, and ages were 6 to 144 months. The breeds were Maltese (n = 30), Poodle (n = 20), Pomeranian (n = 20), crossbreed (n = 18), Yorkshire Terriers (n = 6), Chihuahua (n = 2), Shihtzu (n = 2), Cotton de Tulear (n = 2), Pekingese (n = 1), Pug (n = 1), and Bichon Frise (n = 1). There were 46 males and 57 females, 43 were castrated and 27 were spayed. 80 with MPL and 23 non-affected dogs completed the proposed protocol. Dogs that were too timid, frightened, or overactive to strangers did not been included in this study. Description of dogs with MPL and non-affected was summarized during 10 and 30 seconds.

The each average CPPL and Area 95 during 10 seconds were 2.9 ± 0.81 m, 2.06 ± 0.77 ㎠ in non-affected dogs. CPPL was 3.4 ± 0.86 m in grade Ⅰ group, 3.4 ± 0.50 m in grade Ⅱ group, 3.8 ± 1.20 m in grade Ⅲ group, and 3.6 ± 0.63 m in grade Ⅳ group. The difference between non-affected group and grade Ⅲ group was highly significant in CPPL (p <0.01).

Area 95 in grade Ⅰ was 2.8 ± 0.90 ㎠, 2.7 ± 0.70 ㎠ in grade Ⅱ group, 6.1 ± 4.26 ㎠ in grade Ⅲ group, and 7.3 ± 2.34 ㎠ in grade Ⅳ group. The differences among non-affected group and grade Ⅲ, Ⅳ groups were highly significant in Area 95 (p <0.01).

The average CPPL and Area 95 during 30 seconds were 8.8 ± 2.34 m, 2.6 ± 0.76 ㎠ in non-affected dogs, respectively. CPPL was 8.4 ± 3.02 m in grade Ⅰ group, 8.3 ± 2.20 m in grade Ⅱ group, 10.3 ± 2.12 m in grade Ⅲ group, and 11.3 ± 1.97 m in grade Ⅳ group. The differences among non-affected and grade Ⅲ, Ⅳ group were significant (p <0.05 and p <0.01, respectively).

Area 95 was 3.3 ± 1.16 ㎠ in grade Ⅰ, 4.0 ± 0.84 ㎠ in grade Ⅱ group, 8.2 ± 2.99 ㎠ in grade Ⅲ group, and 11.8 ± 2.86 ㎠ in grade Ⅳ group. The differences among non-affected group and grade Ⅱ, Ⅲ and Ⅳ groups were highly significant in Area 95 (p <0.05, p <0.01 and p <0.01, respectively)

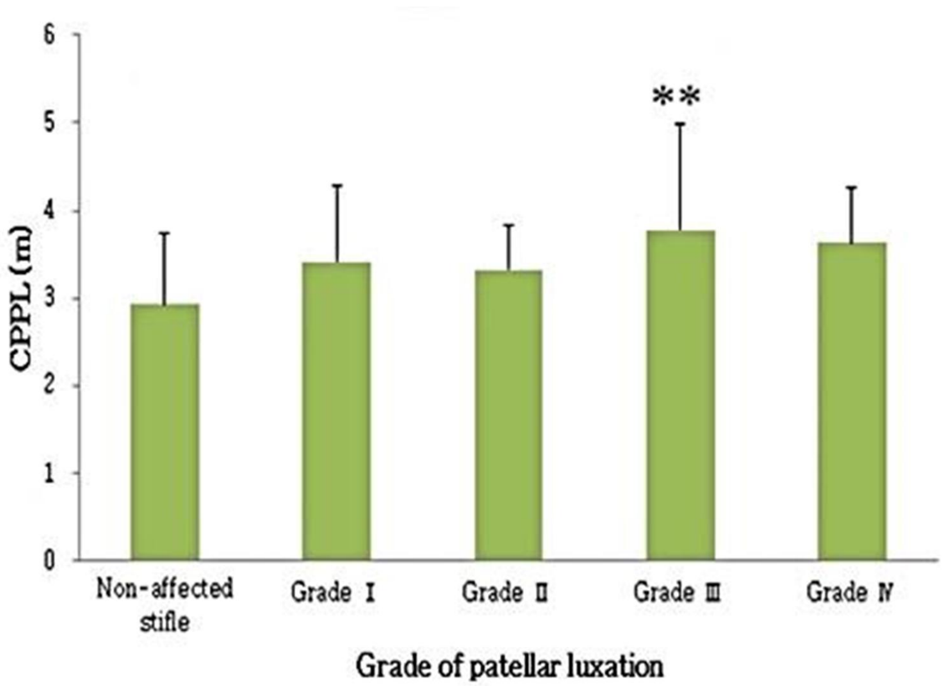

Figure 7. Comparison of the CPPL between non−affected stifle and MPL group for 10 seconds. The graph is shown significant results on grade Ⅳ. ** $p < 0.01$

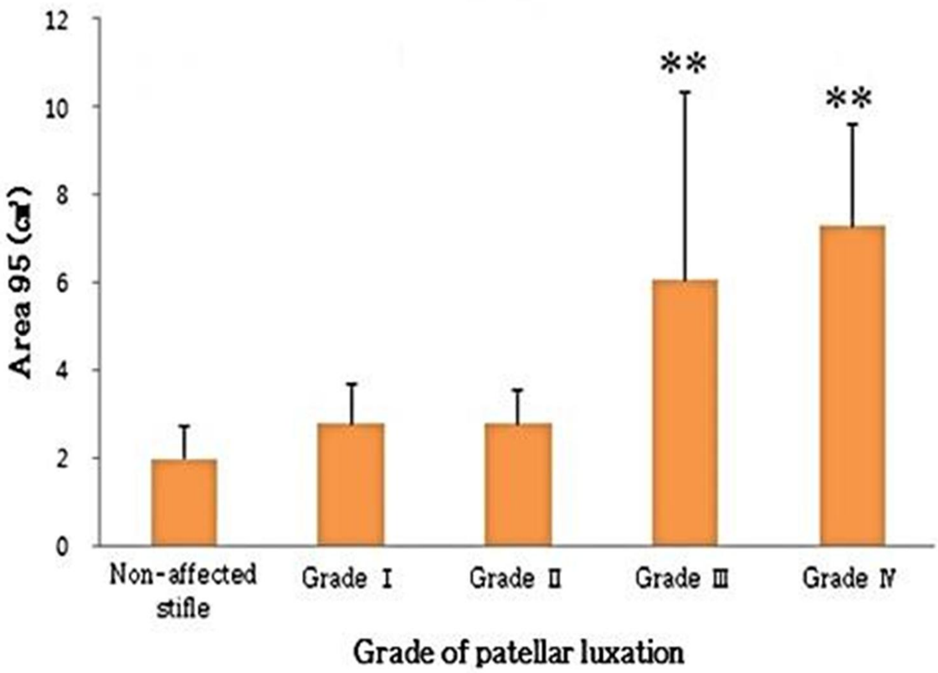

Figure 8. Comparison of the Area 95 between non−affected stifle and MPL group for 10 seconds. The graph is shown significant results on grade Ⅳ. ** $p < 0.01$

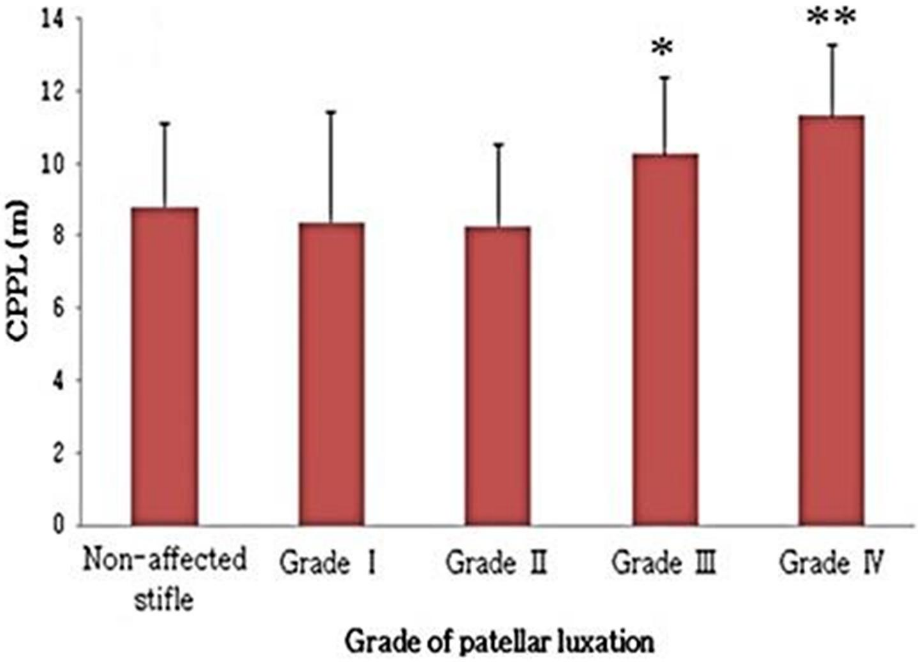

Figure 9. Comparison of the CPPL between non−affected stifle and MPL group for 30 seconds. The graph is shown significant results on grade Ⅳ. * $p < 0.05$, ** $p < 0.01$

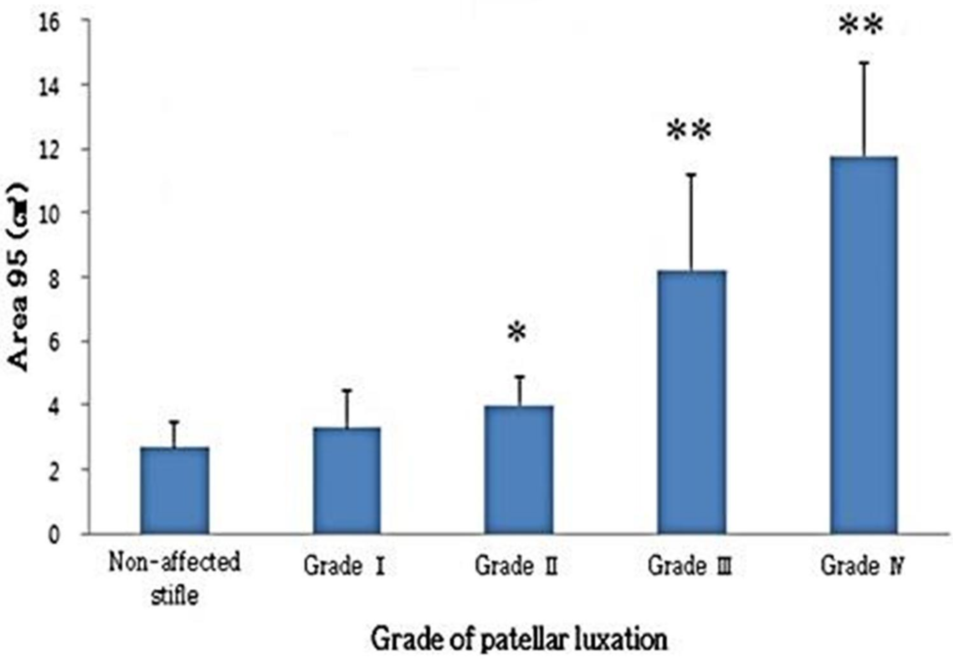

Figure 10. Comparison of the Area 95 between non−affected stifle and MPL group for 30 seconds. The graph is shown significant results on grade Ⅲ, Ⅳ. * $p < 0.05$, ** $p < 0.01$

Ⅱ – 4. Discussion

In previous study involving 14 healthy individuals, WBB was demonstrated sufficiently in quantifying COP trajectory during single−leg stance balance tasks. These significances showed that WBB indicated objective and effective balance tool (Huurnink *et al.,* 2013; Larsen *et al.,* 2014). This study performed the static hindlimb standing in order to evaluate the effect of the body sway of dog with MPL except the forelimb using two plates on the WBB.

Regarding the sampling frequency for clinical COP, previous study in humans suggested that a high sampling frequency is recommended to get reliable values (Scoppa *et al.,* 2013). The CPPL is the sum of distance of the oscillatory movement. Oscillation sway is shorter in small sized dogs than in humans. It means that high frequency is needed to measure the impairment of the dog's musculoskeletal impairment in detail. For that reason, this study used the sampling rate to 100 Hz.

Stairs had significant difference with peak vertical force, impulse in method of physiotherapeutic evaluation as outcome measures of stifle functionality in dogs (Hyytiainen *et al.,* 2013). The dog's forelimbs were picked up on the table slightly and made standing position as dog climbing the stairs to gain more information on the abnormal body way. The position was made the dog as much weight loading on his hindlimb as possible. In clinical experience, using four plates (each limb on the WBB) was in practice difficult and non-rewarding. Because there are so many distracted dogs, they could not be controlled on the WBB. Nevertheless, two plates that measure only the difference between less-affected and affected stifles were specific enough to recognize static weight shift, and it could be reliably used as an outcome measure.

In previous study, use of bathroom scales in measuring asymmetry of hindlimb static weight bearing in dogs with OA in at least one stifle joint, with or without hip joint OA showed reliability and objectivity (Hyytiainen *et al.,* 2012). This study also showed that static evaluation of hindlimb might be differentiated from problematic limb. This study showed significance due to the instability of the joint with extended stifle joint, which the patellar tendon is deflected medially and the proximal tibia is changed biomechanically. WBB can provide data for static standing using computerized posturography in this study. The trajectory of COP in static weight shift between the hindlimbs can be evaluated visually to higher MPL grade especially.

If the medial force on the patella is inadequately placed, a small defect caused by the mechanical force will fail to heal and will degenerate further over time in stifle (van der Zee, 2015). The results of this study indicated that persistence of joint instability and degenerative change of the musculoskeletal system in higher grade MPL could be detected through body sway in CPPL and Area 95.

Three successive recordings of 10 seconds were enough to detect asymmetries in the dislocation of the COP in large dogs with forelimb OA (Manera et al., 2017). This study indicated the significant difference for 10 seconds in small sized dog with MPL except grade Ⅰ and Ⅱ group in Area 95 and CPPL. However, there was no significant result in grade Ⅳ MPL group in CPPL. Grade Ⅳ MPL might have displayed a learned pattern of weight bearing due to biomechanical changes and 10 seconds was considered to be an insufficient time to show the clinical symptoms in the dogs without clinical signs. In this study, there were a relatively large number of dogs with clinical symptoms of grade Ⅱ and Ⅲ, relatively. This may be because a relatively low sample size could result in a potential lack of statistical power. Nevertheless, this study clearly demonstrated that static standing hindlimb is a powerful tool to assess abnormal body sway in dogs with higher grade MPL and advance the objective quantification of weight shifting in limbs. Because it seemed that 30 seconds was enough to detect hindlimb's impairment in the excursion of the COP in this study.

The non-weight bearing phase corresponds with luxation or subluxation of the patella and the gait returns to normal when the luxation spontaneously reduces (Harasen, 2006a). This study did not show significant difference in MPL grade Ⅰ and Ⅱ groups. This means that MPL may be reduced spontaneously.

Because Luxation or subluxation of the patellar represents a mechanical lameness, patellar luxation impedes normal function of the stifle rather than producing significant pain (Harasen, 2006b). There was no significant difference in MPL grade Ⅰ and Ⅱ groups in this study. These results of this study indicated that luxation in COP is not sufficient to cause an increase of body sway. These figures indicated that luxation may be returned naturally, or that there is little pain in the stifle.

The patterns of pressure distribution within paw might be shown location of maximal pressure point and limb COP location as a useful and objective data (Manera *et al.,* 2017). The increase in CPPL and Area 95 showed that the effort to maintain balance increases as shown in this study, especially. This study showed that weight shift of the dog was increased. Weight of both hindlimbs was not loaded steadily and evenly.

Other study also showed significant results in force plate and stairs evaluation, which are similar to the case in which the balance loss as the weight bearing of one sided hindlimb increased when the dogs climbed up and down in stairs. (Hyytiainen *et al.,* 2013). In this study, this study found that the higher the grade, the more body sway increased in CPPL and Area 95. In this study, constant misstepping is a reaction to maintain a balance by avoiding a pain or injury on the WBB. In particular, when compared to figure 8, this study showed significant difference in Area 95 during 30 seconds including the grade Ⅱ group.

Other studies confirmed the significance of hip dysplasia, CCL rupture and meniscal injury through comparison of a dynamic walk and trot kinetics using force plate (Moreau *et al.,* 2014; Vilar *et al.*, 2016). However, this study evaluated the static balance, not the dynamic balance as in the previous study. And There were no significances in limb function between non-affected and affected dogs with grade Ⅰ group both CPPL and Area 95 in this study. Results were showed significant differences in higher grade.

While many larger dogs with grade Ⅰ MPL group encounter clinical symptoms, small dogs are never affected (Harasen, 2006a). In this study, the CPPL and Area 95 in grade Ⅰ was no significant difference despite the increase in evaluation time. This means that grade Ⅰ MPL group is not enough to affect the body sway on the WBB in small sized dog.

Previous study using medical infrared imaging in the thermal pattern of the paw print in the lame hindlimb compared to a non-lame hindlimb concluded that asymmetry index analysis revealed 5% in the healthy group and 36.2% in the lame group in a standing position for 30 seconds (Garcia, 2017). In this study, grade Ⅲ and Ⅳ groups were significantly different from lower grade, suggesting that distance of trajectory point was significantly increased for 30 seconds. Area 95 were greater in grade Ⅱ, Ⅲ and Ⅳ groups as observed in this study, which sway area is greater and this may be any possible compensation to avoid mechanical stress by shifting one sided weight loading towards less-affected side.

At trotting and walking, vertical force was decreased in the ipsilateral forelimb and increased in the contralateral hindlimb in beagle dogs with unilateral hindlimb lameness (Fischer, 2013). Similar to previous studies, the center of mass shifted consistently to the less affected body side depending on the change of time of 10 and 30 seconds. The compensatory weight loading was shifted toward less affected to avoid discomfort.

There were several limitations to this study. First, WBB could be not performed due to lack of cooperativeness, behavioral problem or poor physical condition in some dogs. It was absolutely necessary to enroll calm and obedient dogs to stand in quiet stance for the minimum time required to obtain reliable values. Second, this study used a relative low number of dogs with grade Ⅳ group. Third, this study did not considered changes in CPPL and Area 95 for each bilateral and unilateral MPL. Further study attempts need to compare the CPPL and Area 95 during standing balance between the WBB and laboratory grade force plates in veterinary field. This data can be useful as a tool of improvement that can be compared in pre and post-operative studies of dog with MPL in the future. In conclusion, this study showed that evaluation for 30 seconds with static hindlimb standing is an objective, diagnostic tool in small sized dog with high grade MPL.

CHAPTER Ⅲ

Balance Evaluation after Reconstruction of Medial Patellar Luxation in Small Sized Dog with Wii Balance Board

Ⅲ - 1. Introduction

The MPL is one of the most common orthopedic disorders in small sized dog (Wangdee *et al.,* 2015; Yasukawa *et al.*, 2016). The hip with coxa vara and decreased anteversion of the femoral head and neck is most popular causative. These results of anatomic abnormalities affect lateral bowing and external torsion and displace the extensor muscles of the hindlimb, the quadriceps group, medially. This muscular displacement has an effect on the distal femoral physis, resulting in impaired growth of the medial side, hypoplasia of the medial condyle, a shallow or poorly develop trochlear groove and hypoplasia of the medial trochlear ridge (Fitzpatrick *et al.,* 2012; Pinna *et al.,* 2008). This makes the dog bend its knee and can cause severe friction and rubbing of the surfaces of the joint, progressing to arthritis later, causing pain and chronic lameness (O'Neill *et al.,* 2016).

Articular cartilage, joint capsule, tendon, ligament, bone and muscle affect range of motion (ROM) in maintaining the joint motion. Various conditions have been reported as limiting the ROM including septic arthritis, OA, joint luxation, bone and articular fracture, ligament/tendon rupture and muscle contraction (Marsh *et al.,* 2010). Thigh circumference measurement with a tape is frequently used in veterinary patients as measuring of changes in muscle mass over time (Millis *et al.,* 2014). Measuring the muscle mass symmetry of a standing dog is one of the typical subjective evaluation methods of response to treatment of cranial cruciate ligament disease

(Hyytiainen *et al.,* 2013). Veterinary clinicians may depend on changes in locomotion, duration of weight bearing, stride length, and joint range of motion to assess degree of lameness (Waxman *et al.,* 2008). More than half of dogs with musculoskeletal disease are caused by joint diseases affecting the hindlimb and are commonly associated lameness to unload the affected limb (Fischer *et al.,* 2013).

In quiet stance position, the control of body posture is assumed as a constant action connected with the central nervous system, sight, vestibular and muscular system, which corresponds with the attempt of to keep the center of mass symmetrically to the base of support as a constant action of stabilization of a multilink inverted pendulum (Maurer *et al.,* 2005). The menisci of stifle joint as the afferent information arising from proprioceptors positioned in the capsules, ligaments, and muscle spindles that contributes to joint stability have several important functions, including energy absorption and stress transfer across the stifle joint, postural control (Canapp, 2007; Daneshjoo *et al.,* 2012; Krupkova *et al.,* 2018). The CPPL extracted from the low-cost WBB are validity and comparable with sway measures obtained from laboratory force platforms in the measurement of undisturbed standing balance of young and older adults in a laboratory setting (Clark *et al.*, 2010; Larsen *et al.,* 2014).

Clinically, subjective and objective scales can be used to describe the severity of limb function in dogs. For lameness, the increments of the scale may include varying clinical signs of pain. However, there have not been any attempts to quantitate or compare the results of surgical and non-surgical treatment for static balance using WBB in small sized dogs with medial patellar luxation.

The purposes of this study are to evaluate the reliability of balance using WBB before and after unilateral or single session bilateral surgical reconstruction of dog with MPL.

Ⅲ – 2. Materials and Methods

Animals: A total of 6 dogs with limping and lameness gait attributed to Grade Ⅱ, Ⅲ or Ⅳ MPL were included after orthopedic and radiographic examinations. 9 stifles were confirmed surgically. Dogs with other orthopedic diseases or congenital skeletal deformities in their hindlimbs were excluded. All the patients had clinical signs including unilateral lameness, sometimes difficulty and reluctance to walk, jump and go upstairs. Before surgery, dogs underwent orthopedic, radiographic, and physiotherapy examinations. Data were collected for each dog, including signalment (body weight, breed, sex, and age). If dogs with MPL had bilateral different grade, the only one higher grade was included in this study. Measurements were recorded for 6 dogs before surgery, at the end of each 4 and 8 weeks after surgery.

The ROM of stifle joint: The dROM in the stifle joint were measured in triplicate by use of an electric universal goniometer. Measurements were made for each limb with the dogs awake and positioned in lateral recumbency. The axis of the goniometer was placed over the lateral aspect of the stifle joint axis. The femoral arm was aligned with the greater trochanter and the tibial arm with the lateral malleolus. To measure end of ROM, the joint was slowly flexed or extended until the first indication of discomfort, such as tensing the muscles, pulling the limb away, vocalizing or turning the head slightly, is noted.

Muscle mass: A measuring tape with a spring tension device was used in measuring thigh limb circumference. Measurements were obtained three times with standing hindlimb, and the tape measure was placed around the 70% location of femur. Thigh length was determined by measuring from the tip of the greater trochanter to the distal aspect of the lateral fabella. Mean of the values was calculated and recorded.

Functional scores: Visual gait assessment was performed by observing the dogs individually walking, and trotting on a leash, in a straight line and in a circle. Lameness data provided by the owners to classify the lameness were used in this study. Evaluations consisted of an examination of each dog's physical condition, wherein a score from 1 through 5 (least to most severe) was assigned to characterize the following clinical signs. A score was assigned for lameness, willingness to bear weight on the affected limb while standing, and willingness to lift the contralateral limb. Variables were scored on a scale of 0 to 5 (lameness) or 1 to 5 (willingness to bear weight on affected limb while standing and willingness to lift the contralateral limb) (Table 3).

Table 3. Scoring System used for Hindlimb Examination (Monk *et al.,* 2006)

Variable	Grade	Description
Lameness assessed at a walk	0	No lameness detected at a walk
	1	Intermittent lameness at a walk with come steps that are fully weight bearing
	2	Always uses affected limb at a walk with slight lameness detected
	3	Always uses affected limb but partial weight bearing and obviously lameness
	4	Intermittent non−weight bearing lameness at a walk
	5	Non−weight bearing lameness at a walk
Weight bearing while standing	1	Typical weight bearing on limbs while standing; bears weight evenly on both pelvic limbs.
	2	Stands on foot of affected limb at all times but more weight on unaffected limb.
	3	Stands on foot of affected limb most of the time but with minimal weight bearing.
	4	Touches toes of affected limb to ground with rare or no weight bearing.
	5	No weight bearing on affected limb while standing.
Willingness to lift contralateral limb	1	Readily accepts contralateral limb being lifted and bears weight fully on affected limb.
	2	Offers resistance to lifting of the contralateral limb but bears full weight on the affected limb for > 30 seconds.
	3	Offers moderate resistance to lifting of the contralateral limb and cannot stand for 30 seconds without flexing stifle or hopping.
	4	Offers resistance to lifting of the contralateral limb and tries to sit or move away in < 10 seconds.
	5	Will not allow lifting of the contralateral limb or sits immediately

Static balance assessment: CPPL and Area 95 were acquired using WBB (Nintendo, Japan), a laptop, equipped with Bluetooth and software Balancia® (v2.0, Minto systems, Korea) at 100 Hz. Dogs were placed in quiet stance with their hindlimb on the pressure platform, perpendicular to the ground, and technician remained in front of the animal to attract the dog's attention at a close distance. The path length and area of COP were performed with vertical forces of the only two load sensors. Each paw of hindlimb was centered to be fully loaded on the WBB. When the dog was completely immobile in symmetric position, recording was started. Each three recordings of 30 seconds were obtained from dogs. 10 second interval was allowed between each experimental trial. If the dog either stepped off from the plates during experiment, the examiner lifted the whole body into the air while the WBB were reset.

Surgical procedure: The dogs were anesthetized and prepared for aseptic surgery. All surgical procedures included a parapatellar approach to the stifle joint through a craniolateral skin incision, trochlear sulcoplasty, lateral transposition of the tibial tuberosity and lateral retinacular imbrication. The subcutaneous tissue and skin were closed. The limbs were bandaged after surgery for 7 days. An Analgesic and antibiotic were routinely administered twice a day for seven days. Dogs were discharged to their owners on 5 days.

Statistical analysis: Statistical of changes for surgical interventions over time was performed through One-Way ANOVA. Differences were considered statistically significant when the p-value was <0.05. Values for dROM, muscle mass, lameness, willingness to bear weight on the affected limb, and willingness to lift the contralateral limb, Area 95 and CPPL measures was assessed. All statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS Inc. Version 19.0, Chicago, IL, USA).

Ⅲ - 3. Results

A total of 6 dogs with clinical sign for grade Ⅱ, Ⅲ or Ⅳ MPL with unilateral or bilateral were included. Breeds included Maltese (n=3), Pomeranian (n=1), Chihuahua (n=2). The body weight of enrolled dogs ranged from 4.4 ± 0.3 kg, and ages were 4.9 ± 3.6 years. There were 3 castrated males and 3 spayed females. 3 of 6 dogs were diagnosed with bilateral MPL and the rest were unilaterally affected with MPL. Description of dogs with MPL was summarized (Table 4). The presenting complaint of owners for all dogs was trying not to move, hindlimb lameness, limping and loss of balance.

Table 4. Description of Dogs with Medial Patellar Luxation

No.	Breed	Age (years)	Weight (kg)	Lesion (grade)*
1	Maltese	12	4.7	Bilateral (R 3, L 4)
2	Maltese	5	3.8	R (2)
3	Pomeranian	4	4.4	R (3)
4	Maltese	2	4.3	Bilateral (R 3, L 2)
5	Chihuahua	4	4.7	L (3)
6	Chihuahua	2	4.5	Bilateral (R 3, L 2)

*; R: Right, L: Left

dROM of stifle: Preoperatively, the result of passive dROM was 78.4 ± 9.59°. On post-surgery, dROM were identified improvably on 4 weeks (100.8 ± 6.12°), 8 weeks (111.0 ± 2.21°).

Muscle mass: for thigh muscle atrophy that occurs with MPL, muscle masses to determine the improvement of reconstruction were measured. At 4 weeks after surgery, size of the muscle increased to 1.3 ± 0.54%. At 8 weeks after surgery, sized of the muscle mass showed an increase of 4.1 ± 0.86%.

Lameness and weight bearing: Scores for lameness, willingness to bear weight on the affected limb, and willingness to lift the contralateral limb differ significantly between pre and post-surgery. At 4 weeks after surgery, all groups had improvement as indicated by lower scores for each of the three measures and significant difference was evident between pre and post-surgery.

CPPL: The results revealed no significant difference between pre and post-surgery 4 weeks. Preoperative CPPL was 10.1 ± 0.98 m. At 4 weeks after surgery, CPPL was 9.1 ± 0.72 m. Analysis of CPPL between pre and post-surgery 8 weeks over time revealed a significant ($p < 0.05$). At 8 weeks after surgery, distance of body sway on affected limbs was improved to 9.0 ± 0.80 m.

Area 95: The results revealed significant difference between pre and post-surgery 4 weeks. Preoperative Area 95 was 8.9 ± 2.69 ㎠. At 4 weeks after surgery, Area 95 was 2.7 ± 0.77 ㎠. At 8 weeks after surgery, affected limbs for area of body sway still remained improved significantly comparing with 4 weeks after surgery. At 8 weeks after surgery, distance of body sway on affected limbs was improved to 2.6 ± 0.44 ㎠.

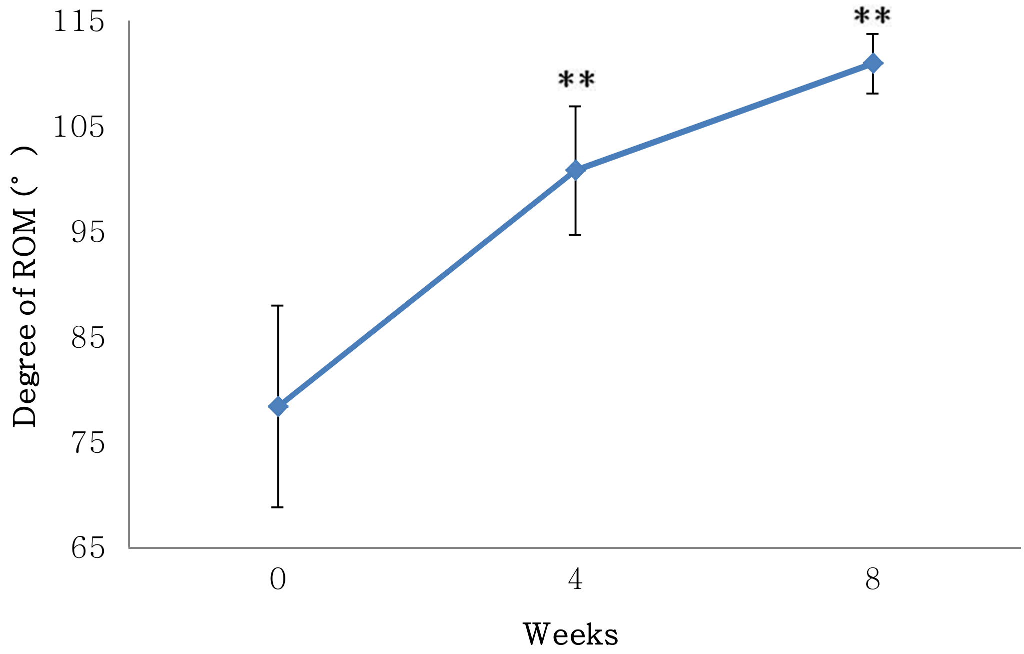

Figure 11. Comparison of the ROM among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

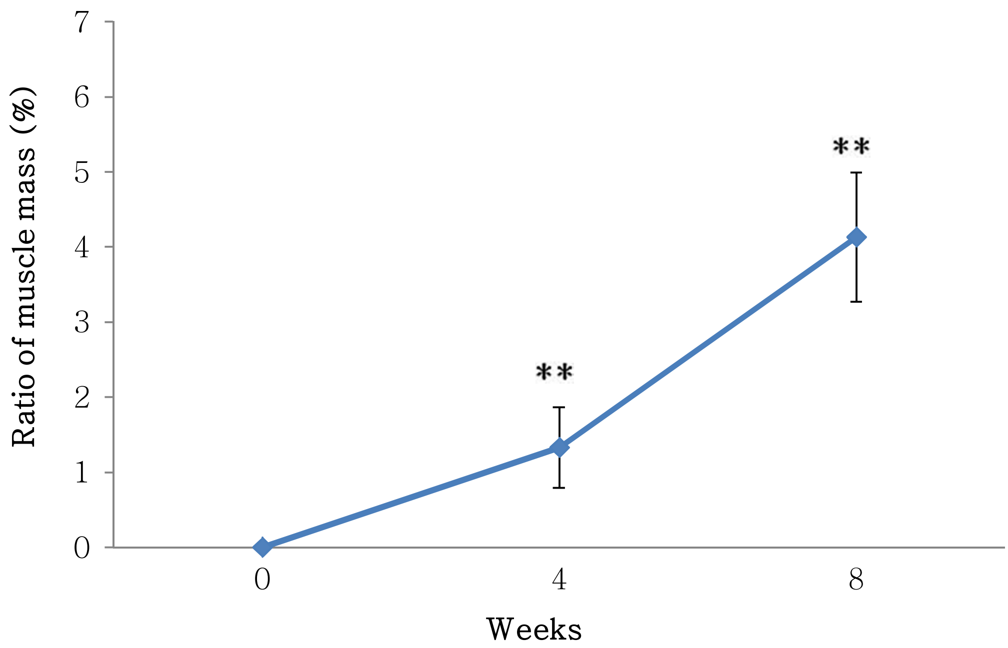

Figure 12. Comparison of the muscle mass among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

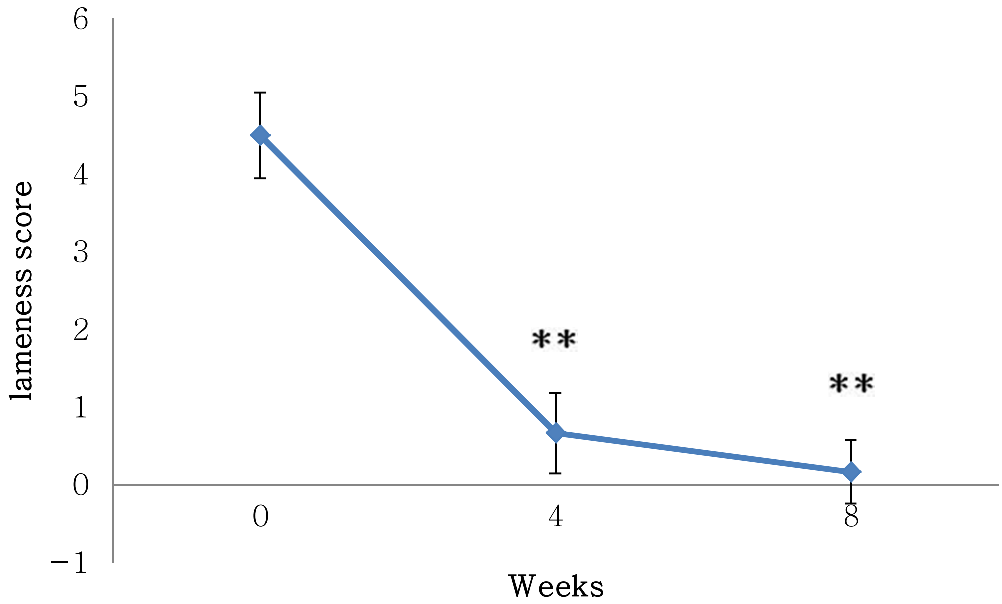

Figure 13. Comparison of the lameness score among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

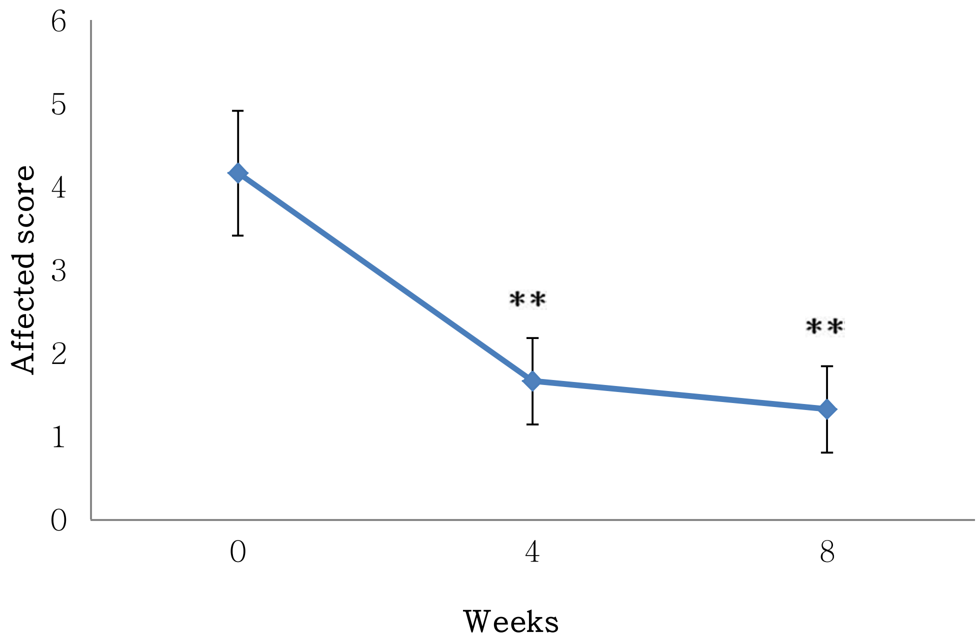

Figure 14. Comparison of the willingness to bear weight on the affected limb while standing score among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

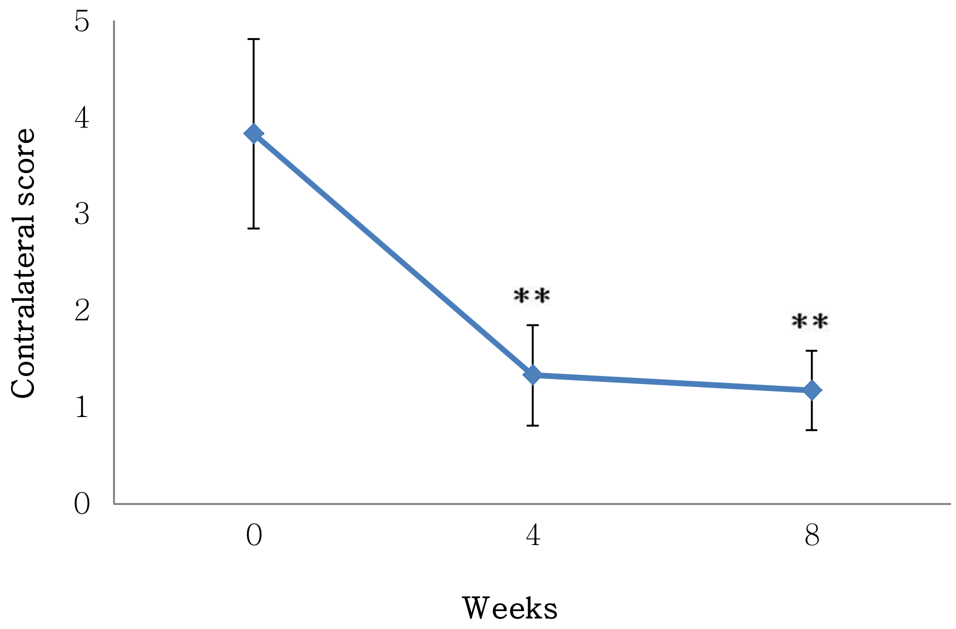

Figure 15. Comparison of the willingness to lift the contralateral limb scores among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

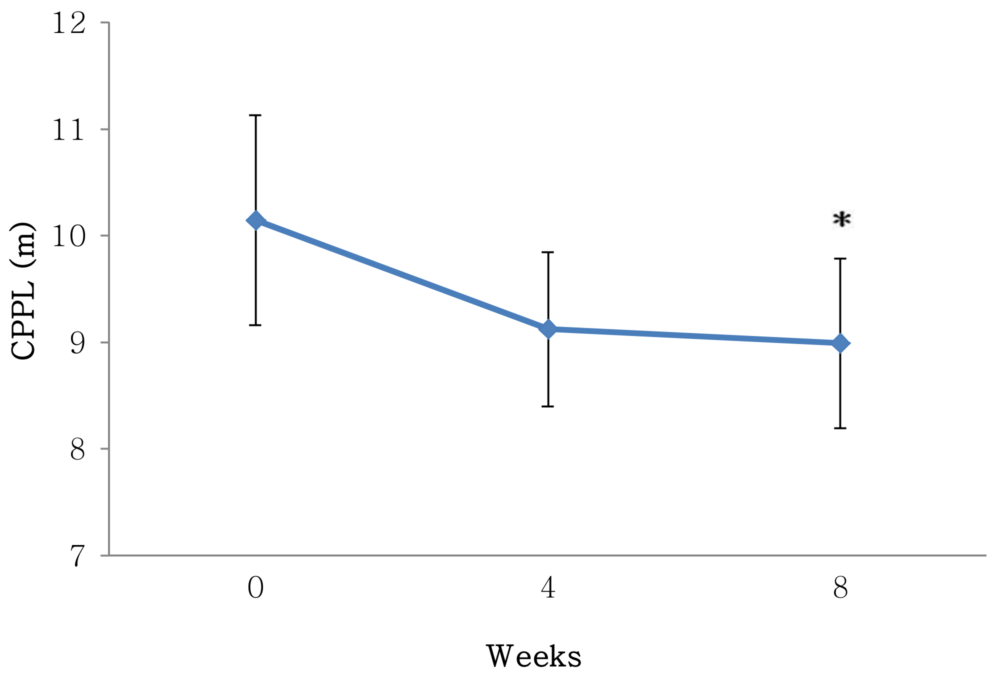

Figure 16. Comparison of the CPPL among pre, post−surgery 4 and 8 weeks. The graph is shown significant results at 8 weeks after surgery. $^{*}p < 0.05$

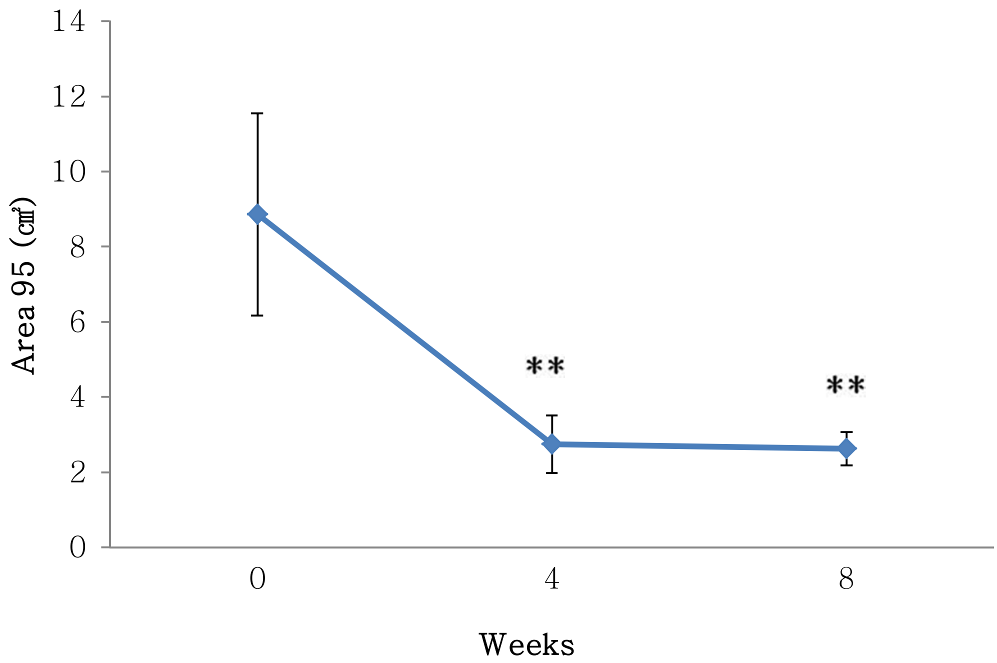

Figure 17. Comparison of the Area 95 among pre, post-surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. $^{**}p < 0.01$

Ⅲ - 4. Discussion

Subjective scoring most accurately reflect force plate analysis when lameness is severe in dogs (Quinn *et al.*, 2007). Total force, contact pressure, area of the force of the affected hindlimb, lameness, and visual analog scale scores were the most reliable and sensitive parameters for assessing pain in acute arthritis cat model (Carroll *et al.*, 2008). This study was designed for lame dog with severe clinical symptoms including lameness, limping and skipping gait. The degree of improvement was measured using WBB for objective evaluation, and the subjective evaluation was conducted using veterinary-assessed functional score. This study was considered objective assessment of body sway using WBB. Objective assessment is as important as owner-assessed signs for measuring improvement of symptoms in clinical performance. This result supported that lame dogs were less stable and dogs with clinical sign of MPL unloaded the affected limb and shifted the center of mass to the non-or less affected side.

In previous study, dog with MPL was observed that unilateral and bilateral MPL had an effect on the ROM of forelimb and hindlimb. either the forelimb or the hindlimb was not capable of normal weight bearing because of reasons such as muscle disorder (Abdelhadi *et al.*, 2013). In this study, it was found that the ROM of the stifle joint showed highly significant difference between pre and post-surgery. On pre-surgery, this may have resulted from compensatory mechanism due to affected sided MPL. Loading only one limb make unstable balance and results in an irregular weight bearing pattern and a compensatory redistribution of limb loading. Dogs had good return to function after post-surgery for dROM, CPPL and Area 95 in this study.

Strength, endurance, appropriate recruitment of muscle fibers, and timing is essential to perform normal joint function. Results of other study revealed muscle atrophy of the surgical leg by 2 weeks, with muscle mass beginning to return between 4 and 8 weeks in dogs with had a cranial cruciate ligament transected, followed by immediate stabilization with an extracapsular procedure (Marsolais *et al.,* 2002; Millis *et al.*, 2015). In this study, there was significant result in muscle mass both pre and post-surgery. This study showed an increase in muscle mass after reconstruction of MPL on 4 weeks (1.3 ± 0.54%), and 8 weeks (4.1 ± 0.86%). There was also significant difference both at 4 and 8 weeks ($p < 0.01$) after surgery. Malalignment of MPL was considered to be the underlying cause of the complex sequence of musculoskeletal changes in the hindlimb. This may cause muscle mass to be hypotrophy due to compensatory mechanism. However, as affected hindlimbs recovered, weight bearing was transferred to recovered hindlimb after surgery. As a results of this study, it was found that the muscle mass of the stifle joint showed highly significant difference between pre and post-surgery. It showed improvement in muscle mass, CPPL and Area 95 over time.

The postoperative lameness score decreased significantly in comparison with the preoperative score at 4 weeks in 55 Pomeranian dogs that were presented with the complaint of MPL (Wangdee *et al.,* 2013). The clinical lameness score was used routinely as part of the orthopedic examination. A lameness was detected by the changes in size and temperature of the thermal image of the paw print of the dogs, and confirmed with force plate orthostatic analysis (Garcia *et al.*, 2017). Although lameness score is not objective tool, this study showed possibility to compare the improvement for lameness score with WBB in CPPL and Area 95. Functional scores differed significantly between pre and post-surgery in this study. As the scores were improved, measurement values of WBB were also improved in this study. A significant difference of stable weight shift was demonstrated following reconstruction of MPL.

In other published studies in which hindlimb lameness was induced in dogs, the vertical ground reaction force parameters were significantly lower in the affected limb and vertical force, vertical impulse were increased in the contralateral hindlimb (O'Connor *et al.,* 1989). During all 420 trials, comparison of force plate and WBB revealed very high Pearson's correlation coefficients of the center of pressure trajectories in human study (Huurnink *et al.,* 2013). In this study, decrease of CPPL and Area 95 indicated that body sway was stable after reconstruction of MPL compared with before surgery without the asymmetrical weight shift. The subjective weight bearing was improved significantly at 4 weeks following surgery.

However, no statistically significant difference was observed until post 8 weeks postoperatively in CPPL. 3 of 6 dogs with clinical symptoms participated in this study had bilateral grade Ⅲ, Ⅳ MPL. Therefore, we considered that body sway seems to have been not significant in CPPL with the standing hindlimbs due to any discomforts within 4 weeks. However, both CPPL and Area 95 showed actually stable body sway at 8 weeks in this study. This study showed lame dogs had body sway to the level of healthy hindlimbs at postoperative 8 weeks on WBB.

A dog with MPL has an increase in the quadriceps angle, presenting in a crouching and toe-in posture with limited locomotion. Medial malpositioning of the tibial tuberosity may lead to biomechanical change of the quadriceps mechanism (Harasen, 2006a; Fitzpatrick *et al.*, 2012). In surgical procedure, the tibial tuberosity may be transplanted to more lateral locations to help in reducing medial pull on the patella. In this study, the recovery of alignment demonstrated improved body sway as the area and distance of weight bearing are reduced at 4 and 8 weeks, postoperatively.

Previous study found a pain-free behavior correlated to a 'Walking with full weight bearing of the operated leg' following canine orthopedic surgery (Rialland *et al.*, 2012). Overall, this study confirmed improvements in postoperative MPL in dogs for ROM, muscle mass, functional score, and static balance assessment. It can be considered that evaluation of symmetry and stability of weight shift with WBB can be linked to stable walking.

I evaluated surgical outcome on pre, post 4 and 8 weeks after MPL repair using a combination of WBB and functional score examinations. Limitations of this study include few dogs, relatively short follow-up, and the subjective nature of the outcome measures. However, methods of evaluation used in this study were chosen based on the validity from the available veterinary literature. The main findings of this study were that WBB is a reliable and valid tool for measuring static body sway on pre and post−surgery in dogs with incidental MPL. These findings demonstrate an equally temporal redistribution of weight to the treated hindlimb. This study showed that evaluations using the subjective scores and objective values in WBB are useful and appropriate tools to prove surgical intervention efficacy in dogs with repair of stifle.

Conclusions

The role of modality has grown gradually in rehabilitation of small animal to monitor the course of treatment and determine prognosis. Previous studies on the validity of COP in large breed dogs are sufficient. However, there is little data in small sized dogs. This study was conducted to evaluate WBB for the body sway in small animal. The very high correlation in each small sized dog and mass on the WBB was confirmed. The WBB that can be evaluate the difference between lower and higher grade MPL was specific enough to recognize the abnormal body sway. On pre and post-surgery, this study showed improvement using WBB in dog with reconstruction of MPL.

As results, this study showed WBB as useful diagnostic and prognostic tool in small sized dog with MPL.

References

Abdelhadi J, Wefstaedt P, Galindo-Zamora V, Anders A, Nolte I, Schilling N. Load redistribution in walking and trotting Beagles with induced forelimb lameness. Am J Vet Res 2013; 74(1): 34-39.

Abujaber S, Gillispie G, Marmon A, Zeni J. Validity of the Nintendo Wii Balance Board to assess weight bearing asymmetry during sit to stand and return-to-sit task. Gait Posture 2015; 41(2): 676-682.

Alam MR, Ji JR, Kim MS, Kim NS. Biomarkers for identifying the early phases of osteoarthritis secondary to medial patellar luxation in dogs. J Vet Sci 2011; 12(3): 273-280.

Aristizabal Escobar AS, de Souza ANA, de Campos Fonseca Pinto ACB, Matera JM. Kinetic gait analysis in English Bulldogs. Acta Vet Scand 2017; 59(1): 77-81.

Bartlett HL, Ting LH, Bingham JT. Accuracy of force and center of pressure measures of the Wii Balance Board. Gait Posture 2014; 39(1): 224-228

Bekkers EM, Dockx K, Heremans E, Vercruysse S, Verschueren SM, Mirelman A, Nieuwboer A. The contribution of proprioceptive information to postural control in elderly and patients with Parkinson's disease with a history of falls. Front Hum Neurosci 2014; 8: 939.

Beloozerova IN, Zelenin PV, Popova LB, Orlovsky GN, Grillner S, Deliagina TG. Postural control in the rabbit maintaining balance on the tilting platform. J Neurophysiol 2003; 90(6): 3783-3793.

Bonnechere B, Jansen B, Omelina L, Rooze M, Van Sint Jan S. Interchangeability of the Wii Balance Board for Bipedal Balance Assessment. JMIR Rehabil Assist Technol 2015; 2(2): e8.

Bottaro A, Casadio M, Morasso PG, Sanguineti V. Body sway during quiet standing: is it the residual chattering of an intermittent stabilization process? Hum Mov Sci 2005; 24(4): 588-615.

Bower KJ, McGinley JL, Miller KJ, Clark RA. Instrumented static and dynamic balance assessment after stroke using Wii Balance Boards: reliability and association with clinical tests. PLoS One 2014; 9(12): e115282.

Brichetto G, Spallarossa P, de Carvalho ML, Battaglia MA, The effect of Nintendo Wii on balance in people with multiple sclerosis: a pilot randomized control study. Mult Scler 2013; 19(9): 1219-1221

Buchner HH, Obermuller S, Scheidl M. Body centre of mass movement in the lame horse. Equine Vet J Suppl 2001; (33): 122-127.

Canapp SO. The canine stifle. Clin Tech Small Anim Pract 2007; 22(4): 195-205.

Carroll GL, Narbe R, Peterson K, Kerwin, SC, Taylor L, DeBoer M. A pilot study: sodium urate synovitis as an acute model of inflammatory response using objective and subjective criteria to evaluate arthritic pain in cats. J Vet Pharmacol Ther 2008; 31(5): 456-465.

Clark RA, Bryant AL, Pua Y, McCrory P, Bennell K, Hunt M. Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. Gait Posture 2010; 31(3): 307-310.

Clark RA, McGough R, Paterson K. Reliability of an inexpensive and portable dynamic weight bearing asymmetry assessment system incorporating dual Nintendo Wii Balance Boards. Gait & Posture 2011; 34: 288-291.

Clark RA, Mentiplay BF, Pu YH, Bower KJ. Reliability and validity of the Wii

Balance Board for assessment of standing balance: A systematic review. Gait Posture 2018; 61: 40–54.

Crook T, McGowan C, Pead M. Effect of passive stretching on the range of motion of osteoarthritic joints in 10 labrador retrievers. Vet Rec 2007; 160(16): 545–547.

Daneshjoo A, Mokhtar AH, Rahnama N, Yusof A. The effects of comprehensive warm–up programs on proprioception, static and dynamic balance on male soccer players. PLoS One 2012; 7(12): e51568.

Doyle RJ, Hsiao–Wecksler ET, Ragan BG, Rosengren KS. Generalizability of center of pressure measures of quiet standing. Gait Posture 2007; 25(2): 166–171.

Fischer SI, Andreas A, Nolte I, Schilling N. Compensatory load redistribution in walking and trotting dogs with hindlimb lameness. Vet J. 2013; 197: 746-752.

Fitzpatrick CL, Krotscheck U, Thompson MS, Todhunter RJ, Zhang Z. Evaluation of tibial torsion in Yorkshire Terriers with and without medial patellar luxation. Vet Surg 2012; 41(8): 966–972.

Foss K, da Costa RC, Rajala−Schuttz PJ, Allen MJ. Force plate gait analysis in Doberman Pinschers with and without cervical spondylomyelopathy. J Vet Intern Med 2013; 27(1): 106−111.

Frost−Christensen LN, Mastbergen SC, Vianen ME, Hartog A, DeGroot J, Voorhout G. Degeneration, inflammation, regeneration, and pain/ disability in dogs following destabilization or articular cartilage grooving of the stifle joint. Osteoarthritis Cartilage 2008; 16: 1327–1335.

Gallegos J, Unis M, Roush JK, Agulian L. Postoperative complications and short−term outcome following single−session bilateral corrective surgery for medial patellar luxation in dogs weighing <15 kg: 50 Cases (2009−2014). Vet Surg 2016; 45(7): 887−892.

Garcia EFV, Loughin CA, Marino DJ, Sackman J, Umbaugh SE, Fu J, Schossler JEW. Medical infrared imaging and orthostatic analysis to determine lameness in the pelvic limbs of dogs. Open Vet J 2017; 7(4): 342−348.

Genthon N, Rougier P, Gissot AS, Froger J, Pelissier J, Perennou D. Contribution of each lower limb to upright standing in stroke patients. Stroke 2008; 39(6): 1793−1799.

Gillette RL, Graig T. Recent developments in canine locomotor analysis: a review. Vet J 2008; 178(2): 165-76.

Goble DJ, Cone BL, Fling BW. Using the Wii Fit as a tool for balance assessment and neurorehabilitation: the first half decade of "Wii-search". J Neuroeng Rehabil 2014; 11: 12.

Hamilton L, Franklin RJ, Jeffery ND. Quantification of deficits in lateral paw positioning after spinal cord injury in dogs. BMC Vet Res 2008; 4: 47.

Harris GF, Riedel SA, Matesi D, Smith P. Standing postural stability assessment and signal stationarity in children with cerebral palsy. IEEE Trans Rehabilitation Eng 1993; 1: 35–42.

Harasen G. Patellar luxation. Can Vet J 2006a; 47(8): 817-818.

Harasen G. Patellar luxation: pathogenesis and surgical correction. Can Vet J, 2006b; 47(10): 1037-1039.

Horak FB. Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? Age Ageing 2006; 35: 2

Huurnink A, Fransz DP, Kingma I, van Dieen JH. Comparison of a laboratory grade force platform with a nintendo Wii Balance Board on measurement of postural control in single−leg stance balance tasks. J Biomech 2013; 46(7): 1392−1395.

Hyytiainen HK, Molsa SH, Junnila JT, Laitinen−Vapaavuori OM, Hielm−Bjorkman AK. Use of bathroom scales in measuring asymmetry of hindlimb static weight bearing in dogs with osteoarthritis. Vet Comp Orthop Traumatol 2012; 25: 390–396

Hyytiainen HK, Molsa SH, Junnila JT, Laitinen−Vapaavuori OM, Hielm−Bjorkman AK. Ranking of physiotherapeutic evaluation methods as outcome measures of stifle functionality in dogs. Acta Vet Scand 2013; 55: 29.

Krupkova O, Smolders L, Wuertz−Kozak K, Cook J, Pozzi A. The pathobiology of the meniscus: A comparison between the human and dog. Front Vet Sci 2018; 5: 73.

Larsen LR, Jorgensen MG, Junge T, Juul−Kristensen B, Wedderkopp N. Field assessment of balance in 10 to 14 year old children, reproducibility and validity of the Nintendo Wii board. BMC Pediatr 2014; 14: 144.

Lohmander LS, Englund PM, Dahl LL, Roos EM. The long−term consequence of anterior cruciate ligament and meniscus injuries:

osteoarthritis. Am J Sports Med 2007; 35: 1756–69.

Madore E, Huneault L, Moreau M, Dupuis J. Comparison of trot kinetics between dogs with stifle or hip arthrosis. Vet Comp Orthop Traumatol 2007; 20(2): 102–107.

Manera ME, Carrillo JM, Batista M, Rubio M, Sopena J, Santana A, Vilar JM. Static posturography: A new perspective in the assessment of lameness in a canine model. PLoS One 2017; 12(1): e0170692.

Marsh AP, Eggebeen JD, Kornegay JN, Markert CD, Childers MK. Kinematics of gait in golden retriever muscular dystrophy. Neuromuscul Disord 2010; 20(1): 16–20.

Marsolais GS, Dvorak G, Conzemius MG. Effects of postoperative rehabilitation on limb function after cranial cruciate ligament repair in dogs. J Am Vet Med Assoc 2002; 220(9): 1325–1330.

Maurer C, Peterka RJ. A new interpretation of spontaneous sway measures based on a simple model of human postural control. J Neurophysiol 2005; 93(1): 189–200.

Mhatre PV. Vilares I, Stibb SM, Albert MV, Pickering L, Marciniak CM, Toledo, S. Wii Fit balance board playing improves balance and gait in Parkinson disease. PM R, 2013 5(9): 769-777.

Millis DL, Taylor AR, Hoelzler M. Orthopedic and neurologic evaluation. In: Canine Rehabilitation & Physical Therapy, 2nd edition. USA: Saunders Elsevier. 2014; 227-242.

Millis DL, Ciuperca IA. Evidence for canine rehabilitation and physical therapy. Vet Clin North Am Small Anim Pract 2015; 45(1): 1-27.

Monk ML, Preston CA, McGowan CM. Effects of early intensive postoperative physiotherapy on limb function after tibial plateau leveling osteotomy in dogs with deficiency of the cranial cruciate ligament. Am J Vet Res 2006; 67(3): 529-536.

Moreau M, Lussier B, Ballaz L, Troncy E. Kinetic measurements of gait for osteoarthritis research in dogs and cats. Can Vet J, 2014; 55(11): 1057-1065.

Mortari AC, Rahal SC, Vulcano LC, da Silva VC, Volpi RS. Use of radiographic measurements in the evaluation of dogs with medial patellar luxation. Can Vet J 2009; 50(10): 1064-1068.

O'Connor BL, Visco DM, Heck DA, Myers SL, Brandt KD. Gait alterations in dogs after transection of the anterior cruciate ligament. Arthritis Rheum 1989; 32(9): 1142-1147.

O'Neill DG, Meeson RL, Sheridan A, Church DB, Brodbelt DC. The epidemiology of patellar luxation in dogs attending primary-care veterinary practices in England. Canine Genet Epidemiol 2016; 3(1): 1.

Pagnacco G, Oggero E, Wright, CH. Biomedical instruments versus toys: a preliminary comparison of force platforms and the Nintendo Wii Balance Board. Biomed Sci Instrum 2011; 47: 12-17.

Park DS, Lee G. Validity and reliability of balance assessment software using the Nintendo Wii balance board: usability and validation. J Neuroeng Rehabil 2014; 11: 99.

Piermattei DL, Flo GL, DeCamp CE. In: Brinker, Piermattei, and Flo's Handbook of small animal orthopedics and fracture repair. 4th ed. St. Louis, Mo. Saunders Elsevier. 2006; 562-565.

Pinna S, Venturini A, Tribuiani AM. Rotation of the femoral trochlea for treatment of medial patellar luxation in a dog. J Small Anim Pract 2008; 49(3): 163-166.

Quinn MM, Keuler NS, Lu Y, Faria ML, Muir P, Markel MD. Evaluation of agreement between numerical rating scales, visual analogue scoring scales, and force plate gait analysis in dogs. Vet Surg 2007; 36(4): 360-367.

Reguera-Garcia, MM, de Souza-Teixeira F, Fernandez JAP. Test-retest reliability of static postural control in people with multiple sclerosis. J Phys Ther Sci 2017; 29(8): 1399-1404.

Rialland P, Authier S, Guillot M, Del Castillo JR, Veilleux-Lemieux D, Frank, D, Troncy E. Validation of orthopedic postoperative pain assessment methods for dogs: a prospective, blinded, randomized, placebo-controlled study. PLoS One 2012; 7(11): e49480.

Roy RG, Wallace LJ, Johnston GR, Wickstrom SL. A retrospective evaluation of stifle osteoarthritis in dogs with bilateral medial patellar luxation and unilateral surgical repair. Vet Surg 1992; 21(6): 475-479.

Ruhe A, Fejer R, Walker B. The test-retest reliability of centre of pressure measures in bipedal static task conditions-A systematic review of the literature. Gait Posture 2010; 32(4): 436-445.

Scaglioni-Solano P, Aragon-Vargas LF. Validity and reliability of the Nintendo Wii Balance Board to assess standing balance and sensory integration in highly functional older adults. Int J Rehabil Res 2014; 37(2): 138-143.

Scoppa F, Capra R, Gallamini M, Shiffer R. Clinical stabilometry standardization: basic definitions acquisition interval sampling frequency. Gait Posture 2013; 37(2): 290-292.

Sharkey M. The challenges of assessing osteoarthritis and postoperative pain in dogs. AAPS J 2013; 15(2): 598-607.

Shumway-Cook A, Anson D, Haller S. Postural sway biofeedback: its effect on reestablishing stance stability in hemiplegic patients. Arch. Phys. Med. Rehabil 1988; 69(6): 395–400

Singleton WB. The surgical correction of stifle deformities in the dog. J Small Anim Pract 1969; 10(2): 59-69.

Tripette J, Murakami H, Ryan KR, Ohta Y, Miyachi M. The contribution of Nintendo Wii Fit series in the field of health: a systematic review and meta-analysis. Peer J 2017; 5: e3600.

van der Zee JH. Lesions in canine stifle joints due to trochleoplasties as treatment for medial patellar luxation. J S Afr Vet Assoc 2015; 86(1): 1245.

Vilar JM, Cuervo B, Rubio M, Sopena J, Dominguez JM, Santana A, Carrillo JM. Effect of intraarticular inoculation of mesenchymal stem cells in dogs with hip osteoarthritis by means of objective force platform gait analysis: concordance with numeric subjective scoring scales. BMC Vet Res 2016; 12(1): 223.

Wangdee C, Hazewinkel HA, Temwichitr J, Theyse LF. Extended proximal trochleoplasty for the correction of bidirectional patellar luxation in seven Pomeranian dogs. J Small Anim Pract 2015; 56(2): 130-133.

Wangdee C, Theyse LF, Techakumphu M, Soontornvipart K, Hazewinkel H A. Evaluation of surgical treatment of medial patellar luxation in Pomeranian dogs. Vet Comp Orthop Traumatol 2013; 26(6): 435-439.

Waxman AS, Robinson DA, Evans RB, Hulse DA, Innes JF, Conzemius MG. Relationship between objective and subjective assessment of limb function in normal dogs with an experimentally induced lameness. Vet Surg 2008; 37: 241-246.

Wiegant K, Intema F, van Roermund PM, Barten-van Rijbroek AD, Doornebal A, Hazewinkel HA, Mastbergen SC. Evidence of cartilage repair by joint distraction in a canine model of osteoarthritis. Arthritis Rheumatol 2015; 67(2): 465-474.

Yasukawa S, Edamura K, Tanegashima K, Seki M, Teshima K, Asano K, Hayashi K. Evaluation of bone deformities of the femur, tibia, and patella in Toy Poodles with medial patellar luxation using computed tomography. Vet Comp Orthop Traumatol 2016; 29(1): 29-38.

위보드를 이용한 소형견의 내측 슬개골 탈구의 진단과 예후 평가

이 신 호
(지도교수 : 정 종 태)

제주대학교 대학원
수의학과

초 록

위보드(Wii® balance board, WBB)는 균형과 관련된 요인인 신체의 흔들림을 측정하고 기록 할 수 있는 장치이다. 압력 중심점의 길이의 합(CPPL)과 95% 신뢰구간 타원 면적(Area 95)은 WBB를 이용하여 평가하였다. 내부적으로 저장된 교정값과 실험적으로 결정된 값의 유의성을 평가하고자 실험을 수행하였다. 측정은 무게가 없는 상태(0 kg)와 0.25 kg씩 무게를 증가시켜 적용한 군(위보드의 각 플레이트의 중심에 0.25 ~ 4 kg)에서 평가하였다. 또한, 소형견에서 CPPL과 Area 95의 상관관계를 분석하기 위해 23 마리(2.3 ~ 7.3 ㎏)의 개를 10 초간 뒷다리 기립 상태로 평가하였다. CPPL과 Area 95의 평균은 무게가 없는 상태에서 각각 10 초 동안 13.4 ± 0.77 m, 22.6 ± 7.55 ㎠ 이었다. 그리고, 무게를 적용한 군과 적용하지 않은 것을 비교하여 유의한 차이를 확인하였다(p <0.01). CPPL과 Area 95 사이의 클래스 간 상관 계수(ICCs)(= 0.91)는 매우

높게 나타났다. 소형견에서 CPPL과 Area 95의 평균치는 각각 2.9 ± 0.81 m, 2.0 ± 0.71 ㎠ 이었다. CPPL과 Area 95 사이의 높은 ICCs(= 0.86)를 나타냈다.

내측 슬개골 탈구(MPL)의 평가에서 MPL을 가진 80 마리의 소형견과 건강한 23 마리의 소형견을 각 10초, 30초 동안 뒷다리 기립 상태의 연구를 수행하였다. 10초 평가 시, 건강한 군과 Ⅲ 등급에서 CPPL의 유의한 차이가 있었다(p <0.01). 10초 평가 시, 건강한 군과 III 그리고 IV 등급에 Area 95의 유의한 차이가 있었다(p <0.01). 30초 평가 시, 건강한 군과 Ⅲ(p <0.05) 그리고 Ⅳ(p <0.01) 등급에 CPPL의 유의한 차이가 있었다. 30초 평가 시, 건강한 군과 Ⅱ(p <0.05), Ⅲ(p <0.01) 그리고, Ⅳ(p <0.01) 등급에 Area 95의 유의적 차이가 있었다.

소형견에서 MPL의 수술 후 개선의 척도를 평가하기 위해 MPL이 있는 6 마리의 개를 이 연구에 포함하여 30초 동안 뒷다리 기립 평가를 하였다. 슬관절의 관절 가동 범위의 신전과 굴곡의 차이(dROM), 근 둘레, 파행 점수, 환측의 체중지지에 대한 의지 점수, 반대측 후지를 들었을 때 환측의 체중지지 점수, WBB의 CPPL과 Area 95가 측정되었다. CPPL은 수술 8주에 수술 전과 유의적 차이가 있었고(p <0.05) 다른 변수들은 수술 4, 8주에 수술 전과 유의한 차이가 있었다(p <0.01).

결과적으로, WBB는 MPL 질환의 소형견에서 진단 및 예후 평가에 유용하고 신뢰할 수 있는 도구가 될 수 있을 것으로 사료된다.

주요어: 위보드, 신체 흔들림, 압력 중심점의 길이, 95% 신뢰구간 타원 면적, 개