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

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Abstract : Wii® balance board (WBB, Nintendo, Japan) is a device that can measure and record the center of pressure path length (CPPL) and 95% confidence ellipse area (Area 95) in relation to body sway. For evaluating measure of improvement after reconstruction of medial patellar luxation (MPL) in small sized dogs, A total of 6 dogs with limping and lameness gait attributed to Grade II, III or IV MPL were evaluated. 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. CPPL was significantly different on pre-surgery compared with post-surgery 8 weeks ($p < 0.05$). Except for CPPL, measured variables were significantly different on pre-surgery compared with post-surgery 4 and post-surgery 8 weeks ($p < 0.01$).

Key words **:** Wii balance board (WBB), center of pressure path length (CPPL), 95% confidence ellipse area (Area 95), medial patellar luxation (MPL), dog.

Introduction

Center of pressure path length (CPPL) and 95% confidence ellipse area (Area 95) that is the entire vertical forces have been shown to be reliable parameters to measure body sway (2,9).

The medial patellar luxation (MPL) is one of the most common orthopedic disorders in small-sized dogs (21,24). The muscular displacement of MPL 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 (18,19).

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, osteroarthritis, joint luxation, bone and articular fracture, ligament/tendon rupture and muscle contraction (13). Thigh circumference measurement with a tape is frequently used in veterinary patients as measuring of changes in muscle mass over time (16). 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 (11). Veterinary clinicians may depend on changes in locomotion, duration of weight bearing, stride length, and joint range of motion to assess degree of lameness (23). 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 (5).

In standing position, the control of body posture is assumed as a constant action of a multilink inverted pendulum 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 (15). The values extracted from the low-cost Wii® balance board (WBB) are validity and comparable with sway measures obtained from laboratory force in human (4,12).

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 MPL.

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

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. All the patients had clinical signs including unilateral lameness, sometimes difficulty and reluctance to walk, jump and go upstairs. 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.

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The ROM of stifle joint

The dROM in the stifle joint were measured in triplicate by use of an electric universal goniometer (BD-AL200, BLUETEC, CHINA) 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

Muscle mass was obtained three times with standing hindlimb, and the tape measure was placed around the 70% location of femur from the tip of the greater trochanter to the distal aspect of the lateral fabella. 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).

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 enrofloxacin (Baytril®-50inj. Bayer, 5 mg/kg) and carprofen (RIMADYL®, Zoetis Inc., 2.2 mg/kg) were administered twice a day for 7 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).

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. The presenting complaint of owners for all dogs

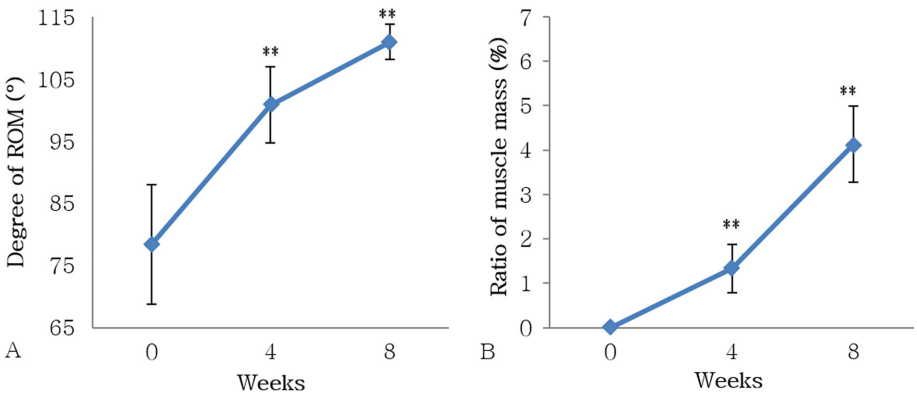

Fig 1. Comparison of the ROM and muscle mass among pre, post-surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. ** $p < 0.01$.

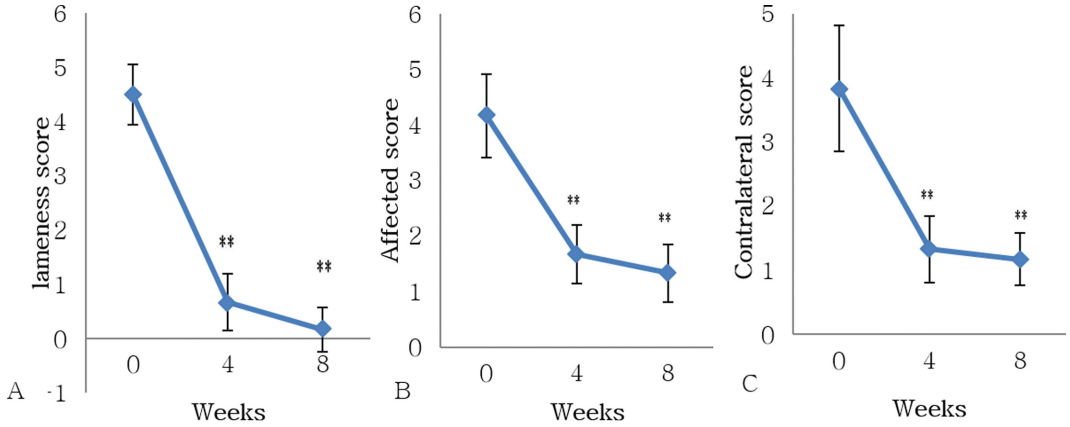

Fig 2. Comparison of the lameness score, willingness to bear weight on the affected limb while standing score, and willingness to lift the contralateral limb scores among pre, post-surgery 4 and 8 weeks. The graph is shown significant results at 4, 8 weeks after surgery. ** $p < 0.01$.

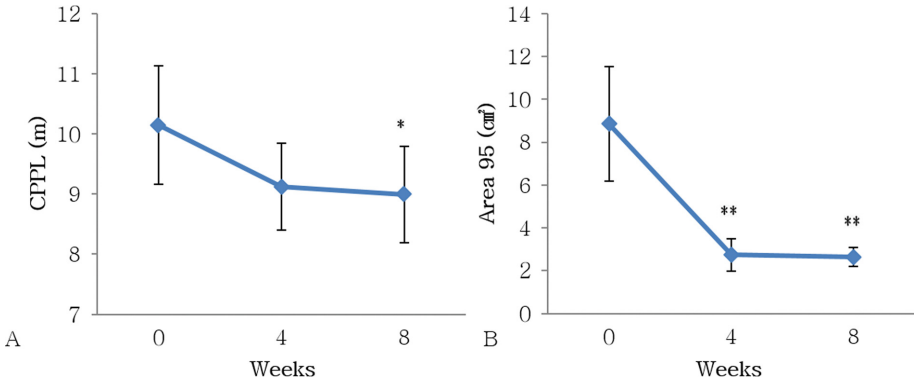

Fig 3. Comparison of the CPPL and Area 95 among pre, post-surgery 4 and 8 weeks. (A) The graph is shown significant result at 8 weeks after surgery in CPPL (B) The graph is shown significant results at 4, 8 weeks after surgery in Area 95. * $p < 0.05$, ** $p < 0.01$.

was trying not to move, hindlimb lameness, limping and loss of balance.

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°) (Fig 1A).

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% (Fig 1B).

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 (Fig 2).

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 (Fig 3A).

Area 95

The results revealed significant difference between pre and post-surgery 4 weeks. Preoperative Area 95 was 8.9 ± 2.69 cm^2. At 4 weeks after surgery, Area 95 was 2.7 ± 0.77cm^2. 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 ± 0.44cm^2 (Fig 3B).

Discussion

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 (3). 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 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, 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 (1). 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 (14,16). 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 ($1.3 \pm 0.54\%$), and 8 weeks ($4.1 \pm 0.86\%$). 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 (22). 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 (7). 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 (17). 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 (10). In this study, decrease of CPPL and Area 95 indicated that body sway was stable after reconstruction of MPL compared with before surgery. 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 (6,8). 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 (20). 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 stability of weight shift with WBB can be linked to stable walking.

This study 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 demonstrated 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.

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