

## **The effect on intralimb coordination while walking with the functional knee brace**

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Proper interjoint coordination is crucial for locomotion while wearing a knee brace. The functional knee braces are to be considered an interlimb coordination, at the same time to be maximized function without interference. The purpose of this study was to evaluate the effect on inter and intralimb coordination while walking with and without knee brace. We conducted using 3D motion analysis system for seven healthy males. Functional knee brace used in three kinds of commercial products. Comparison with brace and no brace condition, intralimb coordination has better in type of constraint knee brace (CTI) and knee stability was improved both constraint and nonconstraint knee brace (patella and neo) compared to the no brace condition. Our result will be utilized to evaluation of the effect and characterization in functional knee brace.

**KEY WORDS:** anterior cruciate ligament, continuous relative phase (CRP), knee brace

### **INTRODUCTION**

Knee injuries, most notably tears of the anterior cruciate ligament (ACL), are particularly severe and occur frequently in many sports. Functional knee braces are widely used today for non-operative treatment, postoperative rehabilitation process and prevent sports injury. The purpose of functional knee bracing has either to shield the reconstructed ligament from increased stress or to stabilize the ACL-deficient knee. Also, ACL braces have evolved from neoprene sleeves to custom-molded carbon fiber.

In gait biomechanics, ACL injured individuals use greater extensor torques at the hip and ankle and a reduced extensor torque at the knee during the stance phase of running and walking. (De Vita et al., 1992) Several groups have tried to recreate the dynamic actions found during cutting sports to evaluate ACL functional bracing during dynamic motion.

As mentioned above, proper interjoint coordination is crucial for locomotion while wearing a knee brace. Thus, functional knee braces are to be considered an interlimb coordination, at the same time to be maximized function without interference. (De Vita et al., 1996) However, most studies have been conducted in the conventional gait analysis measures (e. g. angle-time presentations) and lacking on the effect of interjoint coordination with knee brace.

Quantification of interjoint (e.g. thigh-shank) coordination is very difficult. Relative phase dynamics can provide a better quantification of gait analysis data and they reveal the functional joint stability throughout the gait pattern. Specially, relative phase dynamics utilizes the displacements and velocities of the segments that surround the joint to quantify the joint coordination. (De Vita et al., 1996) There is no studies on the effect of inter and intralimb coordination while wearing knee brace but not investigated the intralimb coordination of the lower extremity during one-legged hopping in patients with ACL reconstruction. (van Uden et al., 2003)

The purpose of this study was to evaluate the effect on inter and intralimb coordination while walking with and without knee brace for healthy people.

## METHODS

Seven males (mean age:  $32.3 \pm 2.7$  yrs; mean height:  $175.2 \pm 3.8$  cm; mean mass:  $76.2 \pm 8.7$  kg) with no history of lower limb pathology volunteered for this study. All subjects gave informed consent according to policy in ethics committee of Korea Orthopedics & Rehabilitation Engineering Center.

Experiment used by 3D motion analysis system (Motion Analysis, Santa Rosa, USA, 2006) composed of 8 infrared cameras (Eagle 4, Motion Analysis, USA), 4 force plates ( $900 \text{ mm} \times 600 \text{ mm}$ , 2 AMTI and 2 Kistler, USA) and a data acquisition system. Reflective marker placed using Helen Hayes marker sets which in 19 anatomical landmarks including pelvis and both lower limbs. All kinematic data of all the markers and analog signals of the force plates were sampled at 120 Hz using real-time software (Cortex 3.0.1, Motion Analysis, USA). (Fig. 1)

Functional knee brace used in this experiment were selected three kinds of products which Neo (Össur, USA), CTI (Össur, USA) and Patella Pro (Ottobock, Germany) commercialized in clinical. (Fig. 1) All subjects were walking at preferred speed wearing a knee brace on the right side, and experimental procedure was conducted randomly. The Subjects were instructed to walk the 10 m gaitway repeatedly for 10 minutes to induce natural gaits while wearing knee brace. Main outcomes were analyzed spatio-temporal, kinematic parameters and CRP.



Fig. 1 Three kinds of commercialized knee brace (neo, CTI and patella-pro in order) and right figure shows marker setting in wearing knee brace.

Phase portraits for the respective segments were created by plotting the segment's angular position versus its angular velocity. The trajectories were then transformed from Cartesian ( $x$ ,  $y$ ) to polar ( $r$ ,  $\theta$ ) coordinates, where the radius was  $r = (x^2 + y^2)^{1/2}$  and the phase angle was  $\theta = \tan^{-1}[y/x]$ . CRP was calculated by subtracting the phase angles of the corresponding segments throughout the stance periods:  $\phi$  shank - thigh =  $\theta$  shank -  $\theta$  thigh, where  $\phi$  is the relative phase between the two interacting segments, and  $\theta$  is the phase angle of the respective segment. CRP values closer to 0 indicate that the segments are moving in a similar fashion, or they are closer to being in phase. Values closer to  $180^\circ$  indicate that the two segments are moving in the opposite direction or they are closer to out of phase. (Barela

et al., 2000)

Statistical differences (SPSS ver. 20.0) between the two conditions (with brace vs. without brace) while walking were analyzed with paired t-tests. In addition, we were analyzed difference between 4 conditions of knee brace (no brace, CTI, neo, patella) using one-way ANOVA test ( $p < 0.05$ ).

## RESULTS and DISCUSSION

In this study, 3 types of knee brace which has different function were conducted. CTI brace has characterized by knee extension constraint, and the others (neo and patella) have a type of nonconstraint knee extension.

While walking with the CTI brace, a maximum knee flexion angle in swing phase and step length was decreased and walking velocity was not statistically different compared to the no brace condition. In addition, the value of CRP was decreased and it means that coordination between shank and thigh was improved.

Previous studies, types of constraint knee brace was increased the knee flexion angle at initial foot contact and was decreased peak posterior ground reaction force during walking, jogging and stair descent in patients with ACL reconstruction (Stanley et al., 2011).

Whereas, our results was showed that constraint knee brace (CTI) was improved in thigh-shank limb coordination and knee stability during walking compared to the no brace condition.

At the neo and patella brace which type of nonconstraint knee brace, a maximum knee flexion angle in swing phase was decreased, but step length was increased likewise the CTI brace. The value of CRP was increased and this result means that coordination between shank and thigh was declined compared to the no brace condition. On the contrary, knee stability improved as SD value of CRP was decreased in all 3 knee braces compared to the no brace condition and it was patella, CTI and neo in order. The relative phase represents the timing of intersegmental movements, whereas the variability of the phase relation (i.e., the standard deviation of the relative phase) is used as a measure of within pattern stability (van Emmerick et al., 1999).

Table 1 Comparison of gait parameters while walking with and without knee brace

|                        |               | No brace  | CTI       | Neo       | Patella-pro |
|------------------------|---------------|-----------|-----------|-----------|-------------|
| Knee flexion angle (°) | Brace limb    | 77.5±2.5  | 70.1±1.5  | 72.1±4.6  | 73.7±2.8    |
|                        | Opposite limb | 76.5±3.6  | 77.2±2.9  | 76.4±4.1  | 77.2±3.8    |
| Step length (cm)       | Brace limb    | 68.0±9.0  | 63.5±5.7  | 79.4±5.0  | 78.5±4.7    |
|                        | Opposite limb | 66.4±7.5  | 64.2±5.1  | 79.0±3.8  | 77.3±2.8    |
| CRP                    | Brace limb    | 103.7±3.0 | 102.2±1.2 | 105.2±2.0 | 107.8±3.0   |
|                        | Opposite limb | 102.3±3.0 | 105.4±0.9 | 104.0±2.3 | 108.0±2.4   |
| SD of CRP              | Brace limb    | 43.1±2.0  | 41.7±2.2  | 42.0±2.5  | 38.6±2.6    |
|                        | Opposite limb | 42.4±3.5  | 41.2±1.4  | 41.7±3.2  | 40.7±1.9    |

A functional knee brace should be designed to apply sufficient force onto the extremity to prevent abnormal motion, particularly excessive anterior tibial displacement, in the ACL injured knee, while allowing normal kinematics for skill performance. Also, it should not be disturbing in coordination on to the lower limb during daily activities.

In this respect, our result was showed that the better limb coordination with the CTI brace and the better knee stability with the patella brace. We are supposed that intralimb coordination had the more increase in type of constraint knee extension brace and knee stability improved both constraint and nonconstraint knee extension brace compared to the no brace condition.

## CONCLUSION

The aim of this study was to evaluate the effect on intralimb coordination while wearing the functional knee brace. Comparative study in brace and no brace condition, intralimb coordination has better in type of constraint knee brace (CTI) and knee stability was improved both constraint and nonconstraint knee brace (patella and neo) compared to the no brace condition. Our result has primary limitation to the experiments for the healthy subjects. Furthermore, there should be conducted for the patients with ACL reconstruction, a various activity and environment. This study will be utilized to evaluation of the effect and characterization in functional knee brace.

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