



Research Article

Immediate Effects of an External Rotation-Restricting Knee Brace on Knee Osteoarthritis: Evaluation Using AI-Based Motion Analysis

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Abstract

A novel knee brace (CBM knee brace) designed to reduce the external rotation moment of the lower leg was developed for patients with medial knee osteoarthritis (knee OA). This study aimed to investigate the immediate effects of the CBM knee brace on knee adduction moment and tibial external rotation moment during gait. A total of 12 patients (12 knees; 9 females and 3 males; mean age: 69.8 years) with medial knee OA were included. Gait analysis was performed under two conditions: without the brace and with the CBM knee brace. Frontal plane motion during a 5-m walk was recorded using a video camera and analyzed with an AI-based motion analysis application (MYOacto). The results showed that the knee adduction moment significantly decreased from 3.90 Nm (no brace) to 2.78 Nm (with CBM brace). Similarly, the tibial external rotation moment significantly decreased from 2.43 Nm to 1.29 Nm with brace application. These findings suggest that the CBM knee brace is effective in correcting the tibial external rotation moment. Future studies should include a larger sample size to evaluate its effects on pain reduction and improvement in gait function. Additionally, determining the optimal extent of moment reduction remains an important subject for further investigation.

Keywords: Knee osteoarthritis; Adduction moment; Tibial external rotation moment; Knee brace; AI analysis

Introduction

Knee bracing is widely used as a conservative treatment for knee osteoarthritis (OA), particularly in medial knee OA, where most brace designs aim to reduce the knee adduction moment [1,2]. However, during knee joint motion, the tibia exhibits an external rotation tendency during flexion. Excessive external rotation moment has been suggested to contribute to pain through increased load on the medial meniscus and medial collateral ligament, as well as elevated intra-articular pressure [3,4,5]. Despite this, conventional knee braces primarily focus on frontal plane control, and insufficient attention has been paid to rotational control. The purpose of this study was to develop a novel knee brace with both varus correction and external rotation-restraining functions (Clinical Balance for Motion: CBM knee brace) and to investigate its immediate effects. This study was conducted with material support provided by the Orthotic Device Laboratory, Inc. The authors declare no other conflicts of interest.

Subjects and Methods

A total of 12 patients (12 knees) diagnosed with medial knee osteoarthritis (OA) were included in this study (9 females and 3 males). The mean age was 69.8 ± 5.4 years, with a mean height of 156.0 ± 5.4 cm and a mean body weight of 58.0 ± 8.9 kg. Radiographic evaluation showed a femorotibial angle (FTA) of $178.7 \pm 1.8^\circ$. According to the Kellgren–Lawrence (KL) classification, 1 knee was graded as KL I, 6 knees as KL II, 3 knees as KL III, and 2 knees as KL IV. This study was conducted with the approval of the Ethics Committee of Saitama Prefectural University. All participants were fully informed of the purpose and methods of the study, and written informed consent was obtained prior to participation.

Structure of the Knee Brace

The newly developed knee brace was named the Clinical Balance for Motion (CBM) knee brace, reflecting its function of adjusting body alignment while maintaining the continuity of movement (Figure 1). The magnitude of the corrective force can be modified by altering three types of straps. The knee joint axis incorporates bilateral coil spring supports, which are removable. The use of coil springs minimizes misalignment with the knee joint axis and prevents distal slippage during brace wear. The strap system is designed to prevent excessive tibial external rotation by applying a force in the internal rotation direction. In addition, varus alignment of the knee is corrected by applying tension from the lateral aspect of the knee joint axis toward the medial aspect of the thigh (Figure 1).

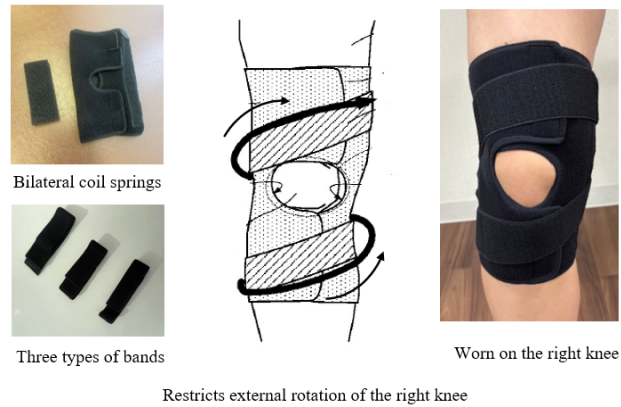


Figure 1: CBM knee brace

Measurement Method

Frontal plane motion during a 5-m walk was recorded using a video camera while participants walked in synchrony with a metronome set at 100 beats per minute (BPM). The recorded videos were analyzed using an AI- based motion analysis application (MYOacto, ORGO Inc.) [6]. Knee adduction moment and tibial external rotation moment were calculated and compared before and after the application of the CBM knee brace. Statistical analysis was performed using IBM SPSS Statistics 26, applying the Wilcoxon signed-rank test, with the level of significance set at less than 5% ($p < 0.05$).

Results

The knee adduction moment significantly decreased from 3.90 ± 1.69 Nm without the brace to 2.78 ± 1.12 Nm with the CBM knee brace, corresponding to a reduction of approximately 1.1 Nm. Similarly, the tibial external rotation moment significantly decreased from 2.43 ± 0.72 Nm without the brace to 1.29 ± 0.51 Nm with the CBM knee brace, also representing a reduction of approximately 1.1 Nm (Table 1).

	Without brace	With CBM Knee brace
Knee adduction moment (Nm)	3.90 ± 1.69	$2.78 \pm 1.12^*$
Tibial external rotation moment (Nm)	2.43 ± 0.72	$1.29 \pm 0.51^*$
*: $p < 0.05$		

Table 1: Knee adduction moment and Tibial external rotation moment (mean ± standard deviation).

Discussion

The tibia exhibits a physiological tendency to externally rotate during knee flexion. However, excessive external rotation moment may increase compressive and shear stress on the medial meniscus, elevate tension in the medial collateral ligament, and raise intra-articular pressure [3-5]. These factors are considered to increase the risk of knee pain by augmenting the mechanical load on medial knee structures. In the present study, the CBM knee brace demonstrated not only a reduction in the knee adduction moment but also a reduction in the tibial external rotation moment. These findings suggest that the external rotation-restraining mechanism of the brace may contribute to decreasing mechanical stress on the medial compartment of the knee. On the other hand, the observed reduction in the external rotation moment itself may have clinical significance. However, the optimal magnitude of reduction required to achieve pain relief remains unclear and should be investigated in future studies. Excessive restriction of external rotation may interfere with the natural rotational biomechanics of the knee and potentially increase the risk of joint overload or injury, such as medial displacement of the knee or increased dynamic valgus [7]. Therefore, consideration of rotational alignment is important in knee joint assessment, as external rotation may also contribute to individual differences in pain presentation. Furthermore, pain reduction is closely associated with improvements in gait ability and quality of life [8]. This study has several limitations, including the small sample size and the lack of comparison with other types of knee braces. Future studies with larger sample sizes are needed to clarify the relationship between rotational control, pain reduction, and functional outcomes.

Conclusion

The CBM knee brace may contribute not only to the reduction of the knee adduction moment but also to the suppression of the tibial external rotation moment. These findings suggest that rotational control could represent a novel therapeutic strategy for knee osteoarthritis.

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