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## Custom-made hinged knee braces with extension support can improve dynamic balance

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## ABSTRACT

**Background/Objective:** We investigated whether custom-made hinged knee braces can facilitate knee extensor and flexor strength and influence functional performance as compared with other knee braces. **Methods:** We enrolled 28 healthy young participants with no history of physical activity or brace use. The participants executed functional performance tests under the following 5 conditions: 1) without a knee brace, 2) wearing a knee sleeve, 3) wearing a hinged knee brace without assistance, 4) wearing a knee brace with extension support (KBE), and 5) wearing a knee brace with flexion support (KBF). The KBE and KBF were custom-made hinged knee braces equipped with rubber tubes. The functional performance tests performed assessed maximal isokinetic strength, single-leg jumping height/distance, anterior and posterior reach distance on a single leg, and dynamic balance ability.

**Results:** The benefit of the custom-made hinged knee brace was observed only during the anterior reach distance on a single leg. The KBE allowed a significantly greater single-leg anterior reach distance when compared to that in the no brace condition. There was a significant relationship between the improvement in the single leg anterior reach distance with KBE and the changes in isokinetic knee extension with KBE compared to the no brace condition. With regard to other parameters, there were no differences compared with the use of other knee braces and thus no apparent benefit.

**Conclusion:** Our findings suggest that using a KBE enhances performance during dynamic balance activity in individuals who benefit from improved knee extension strength.

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## Introduction

Fabric-based knee braces and prophylactic braces are prescribed for instability following bone or soft tissue injuries to the knee.<sup>1</sup> Hinged knee braces were reported to increase dynamic balance and landing stability after a jump during locomotion and when performing athletic tasks.<sup>2</sup> Some reports also suggested that hinged knee braces improve proprioception in the knees of patients with anterior cruciate ligament injuries.<sup>1,3–5</sup> These findings suggested that wearing hinged knee braces increases proprioceptive input around the knee and improves functional performance involving dynamic balance ability. However, wearing the prophylactic knee brace may inhibit the functional performance of healthy participants, such as speed during the forward sprint, because of

decreased peak torque, and torque acceleration energy.<sup>6</sup> The effect of braces on functional performance remains unclear, including in activities such as the one-leg hop, figure-of-eight run, stair climbing, walking, cutting, agility runs, straight running, and bicycle ergometry.<sup>7</sup>

Invasive surgeries of the knee such as anterior cruciate ligament reconstructions often causes imbalance of muscular strength, such as altered hamstrings-to-quadriceps ratio.<sup>8,9</sup> In addition, those undergoing invasive surgeries of the knee may exhibit decreased functional performance tests including hopping and balance tasks.<sup>10–12</sup> Therefore, it was thought that external support for a poorly functioning knee to compensate for impaired muscular strength was necessary after injury or surgeries. The development of a new, easy-to-use assistive device for poor knee function and flexion and extension support is needed.

Recently, greatly improved mechanical efficiency was observed based on the elasticity of rubber that led to the development of hinged knee braces that can assist in extending and flexing the knee.<sup>13</sup> The available evidence suggests that these braces reduce

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the knee adduction moment during gait and can provide flexion support during the swing phase in patients with osteoarthritis.<sup>13</sup> Hinged knee braces with extension and flexion support are able to maintain or increase joint torque, in contrast with common knee braces that only improve joint position sense through proprioceptive input.<sup>14–16</sup> Thus, hinged knee braces may improve functional performance involving muscle strength, single leg jumping, and/or dynamic balance.

The purpose of the present study was to investigate whether hinged knee braces with assistive support improve functional performance including muscle strength, jumping, and dynamic balance, in a comparison with other knee braces. It was hypothesized that wearing hinged knee braces with assistive support would enhance the functional performance resulting from an increase in knee joint torque.

## Methods

### Participants

A total of 28 healthy participants with no exercise habits and brace use were recruited for the study (13 men, 15 women; age:  $21.5 \pm 0.6$  years; height:  $164.3 \pm 8.2$  cm; weight:  $56.7 \pm 8.6$  kg). Those with orthopedic disorders, limited range of joint motion, pain, or severe dysfunction such as sudden knee buckling during running, climbing down stairs, and landing movements were excluded. This study was approved by the Research Ethics Committee of Seijoh University (16 PT06). The participants provided informed consent after receiving an explanation of the content of the study using printed materials.

### Knee braces and conditions

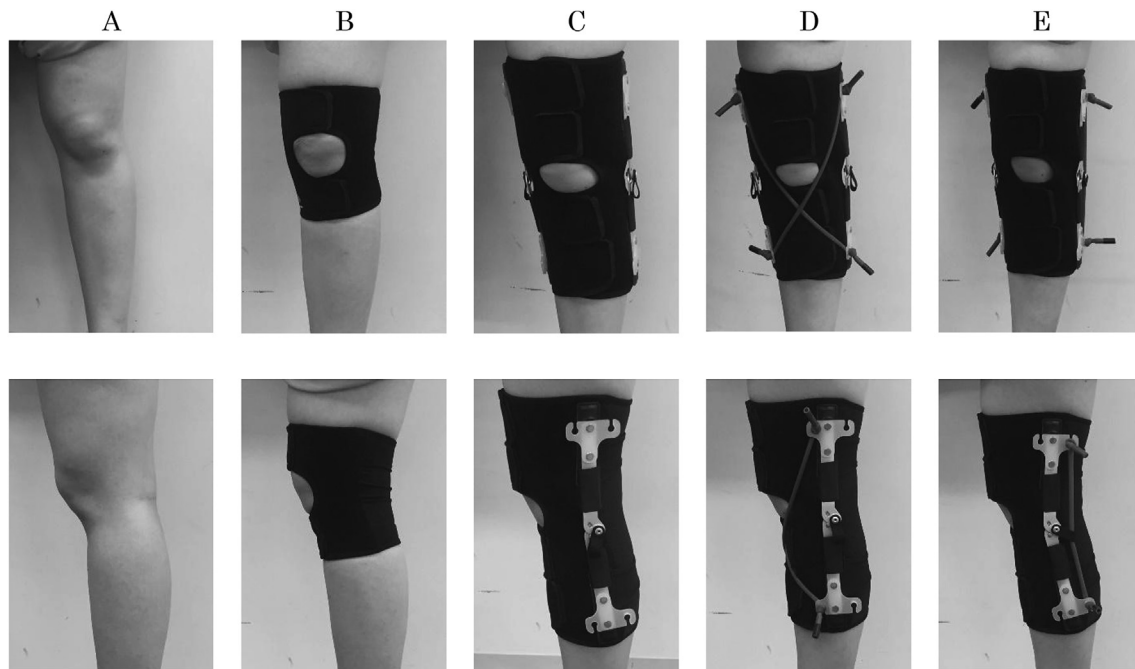
The dominant leg of participants was determined based on the question “Which foot do you use to kick the ball?” The non-

dominant leg was defined as the “supporting leg”, on which the knee braces were placed. Each participant performed tasks under the following conditions: 1) without a knee brace (no brace), 2) wearing a knee sleeve without struts (ZAMST EK-1, Nippon Sigmax Co., Ltd, Japan), 3) wearing a hinged knee brace (Geltex Light Sports, Nippon Sigmax Co., Ltd, Japan), 4) wearing a knee brace with extension support (KBE), and 5) wearing a knee brace with flexion support (KBF) (Fig. 1). Of these, the hinged knee brace, KBE, and KBF were produced by the staff of the Matsumoto prosthetics and orthotics manufacturing company limited. The KBE and KBF were provided by equipping the custom-made hinged knee braces with rubber tubes (Fig. 1D and E). Rubber tubes that produced an elastic force of 2 kg with a length of 21 cm were used. The KBF assisted with production of knee flexion of 1.29, 0.54, and 0 Nm, at 0, 15, and from 30 to 90° of knee flexion, respectively. Further, the KBE assisted with production of knee extension of 2.48, 3.67, 4.53, 4.64, 4.10, and 3.24 Nm, at 0, 15, 30, 45, 60, 75, and 90° of knee flexion, respectively. Measurements for functional performance were performed for 5 days, and a different type of brace and type of assessment were randomly assigned for each day. Further, functional performance tests were randomly provided for each participant.

### Functional performance

#### Maximal isokinetic muscle strength in knee extension and flexion

Maximal isokinetic muscle strength was measured using an isokinetic dynamometer (Isoforce GT-360, OG GIKEN Co., Ltd, Japan). The participants were seated with the hips in 70° flexion, and restraint straps were placed at the waist and distal femur of the limb, thereby minimizing compensatory movement. The axis of the dynamometer was aligned to the lateral femoral epicondyle at 90° knee flexion, and the force arm cuff was fixed 2 cm above the medial malleolus. At the signal to start, the participants were asked to perform isokinetic flexion and extension of the knees at angular



**Fig. 1.** The knee brace conditions used in this study. The five conditions are shown in the upper column as an anterior view and in the lower column as a lateral view: (A) no brace, (B) knee sleeve, (C) hinged knee brace without support, (D) knee brace with extension support (KBE), (E) knee brace with flexion support (KBF). KBE and KBF were provided by equipping the custom-made hinged knee braces with rubber tubes.

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