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Original Article

Knee joint angle sensing in healthy young adults using flexible orthosis with different wearing pressure

Hiroaki Yamamoto, RPT[1, 2)*], Chikamune Wada, PhD[2)]

[1)] *Department of Physical Therapy, Fukuoka Tenjin Medical Rehabilitation Academy: 4-3-7 Watanabedori, Chuo-ku, Fukuoka-shi, Fukuoka 810-0004, Japan*
[2)] *Department of Life Science and System Engineering, Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology, Japan*

Abstract. [Purpose] To investigate the effects of a flexible brace, by analyzing whether its usage; the difference in wearing pressure could change the joint position sensation in healthy participants; and develop a flexible knee brace for patients with knee osteoarthritis. [Participants and Methods] The study included eight healthy males with 14 knee joints (mean age, 22.0 ± 3.1 years). To measure joint position sense, an "angle reproduction test" was performed in three experimental conditions: 1) participants not wearing the brace, 2) the brace was secured with an appropriate force, and 3) the brace was fully secured using hook-and-loop fasteners. [Results] No significant difference was observed among groups comprising of those not wearing, those wearing with the standard force, and those wearing with the tight force. When the maximum hook-and-loop fastener was squeezed, the sensory error in joint position was maximized at both 30° and 60° flexion. [Conclusion] Joint position sense improvement was confirmed to be poor by orthosis, and an error occurred in the joint position sense by increasing the wearing pressure in orthosis. In future, measurements should be performed on patients with knee osteoarthritis who have decreased joint position sense and verify the effect of different wearing pressures verified.

Key words: Knee orthosis, Joint position sense, Wearing pressure

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INTRODUCTION

In recent years, with the rapid aging of the population in Japan, the incidence of locomotor disorders has been steadily increasing. In particular, in load joints such as the knee joint, degenerative changes occur due to mechanical stress, and knee osteoarthritis (hereinafter referred to as knee OA) is likely to develop and progress. It is predicted that the number of patients with knee OA will increase in the future and increased medical costs for the treatment will be a social problem; thus, an urgent solution is necessary[1)]. During the physical therapy for patients with knee OA, muscle strengthening exercise is generally selected as the primary treatment to increase the intra-articular pressure to disperse the joint burden by increasing the knee joint support. Because, muscle weakness can reduce the perception of joint angles and ability to detect slight movements. Therefore, to improve activities of daily living, sufficient muscle strength should be secured and to obtain a sense of joint proprioception[2)]. Proprioceptive sensation is necessary for proper postural control and includes the function of joint position sensation[3)].

Knee orthosis therapy for patients with knee OA has been established as a general treatment method and is also recommended for patients with grade B and evidence level 1 in the Knee Osteoarthritis Physical Therapy Practice Guidelines[4)]. Knee orthosis for knee OA is classified into hard orthosis. The hard orthosis is expensive, with low usage or continuation rate

*Corresponding author. Hiroaki Yamamoto (E-mail: yamamoto@dmr.ac.jp)

is low due to its expensive cost and feeling of discomfort while wearing[5], whereas soft orthosis is inexpensive and easy to wear, with high usage and continuation rates, and thereby frequently used in clinical practice[6]. In addition, the joint position sense has been reportedly improved by wearing a soft orthosis, suggesting that the soft orthosis has a neurophysiological effect due to local compression[7].

However, a previous study focused on the presence or absence of braces and did not investigate the wearing pressure, which is an advantage of soft braces[7]. Studies related to wearing pressure of orthosis have been reported in the sports field targeting stop-jump movements[8]; however, no studies have examined its effects on joint position sense in the rehabilitation field. Skin contact and pressure receptors have been reported to affect joint position sense[9].

Therefore, we hypothesize that changing the wearing pressure can improve joint position sensation and also affect neurophysiological effects. This study aimed to analyze the effect of pressure differences in the soft knee brace on the position sensation of the knee joint in healthy participants and to develop a new soft knee brace for knee OA.

PARTICIPANTS AND METHODS

A total of 8 healthy males with 14 knee joints (mean age, 22.0 ± 3.1 years; height, 171.3 ± 5.1 cm; weight, 67.8 ± 8.0 kg; and body mass index, 23.1 ± 3.0) and those without orthopedic and neurological history. In this study, in accordance with the Declaration of Helsinki, the purpose and contents of this study were fully explained to participants and consent was obtained in advance, and the measurement was carried out after confirming voluntary participation. This study was conducted after obtaining approval from the Ethics Review Committee of Fukuoka Tenjin Medical Rehabilitation College (approval number 202-1).

To measure the joint position sense, an "angle reproduction test" was used[10], where participants were asked to move their ipsilateral limb (e.g., the right leg) until they felt that both knee joint angles were the same after the limb (e.g., the right leg) was moved by the examiner. Participants were asked to wear eye masks to block their vision, and no clothes were worn onto the leg. Participants were asked to sit with lower leg drooping position. The target knee joint angles were 30° and 60° flexion, and the examiner randomly set the knee joint as the measurement angle. Knee angle was measured using a video camera (Panasonic Corporation HC-WX985M, Osaka, Japan), and video markers were attached to the greater trochanter of the femur, the lateral condyle of the femur, and the lateral malleolus of the ankle. The AVCHD video recording mode was set to 1080/60 p mode, and the number of camera pixels was set to 1,920 × 1,080 vertical and horizontal pixels, respectively. Thereafter, the still image was converted from a video, and the angle was calculated using the image processing software ImageJ (National Institute of Health). Maeoka et al.[11] reported that the joint angle measurement with ImageJ using a video camera had high intraclass correlation coefficients of ≥0.97 for both intra- and inter-rater reliability, then the Image J was performed. The examiner passively extended the knee joint from the measurement start limb position (about 90° flexion) to the predetermined angle. After holding the knee joint at the predetermined angle for 3 s, the knee joint was returned to about 90° flexion. Moreover, participants were instructed to voluntarily extend the knee joint until they felt the same angle as the examiner extended. The voluntary extended knee joint was named as "reproduced angle", and held for 3 s. The video camera was placed so that the camera was perpendicular to the sagittal plane. An open-type soft knee orthosis (facilitated supporter: Nippon Sigmax Co., Ltd., Tokyo, Japan) was used. Brace size was indexed by the length around the thigh, 0.1 m above the center of the patella. A numerical size close to the median of the brace was used. The three experimental conditions were as follows: 1) the participant did not wear the brace (not wearing condition), 2) the brace was fastened with an appropriate force (standard force condition), and 3) the brace was fastened using the hook-and-loop fastener of the fully tightened brace (tight force condition). The order of experimental condition was randomized for each participant, and the measurement was performed three times each, with the average value adopted as the measured value.

The Kruskal-Wallis test was used to examine the difference among three experimental conditions (not wearing, standard force, and tight force), and Tukey's method was used for subsequent multiple comparisons. The JSTAT for Windows was used for statistical analysis, and the significance level was set to 5%.

RESULTS

Table 1 shows the error in the position sense for 14 knee joints of 8 participants. No significant difference was observed among all groups of not wearing, standard force, and tight force; however, the largest errors in joint position sense for both angles were obtained in the tight force condition.

Table 1. Joint position sense error

	Knee flexion 30°	Knee flexion 60°
Not wearing (°)	2.5 ± 1.5	4.2 ± 2.8
Standard force (°)	3.0 ± 2.7	3.7 ± 2.0
Tight force (°)	3.8 ± 1.8	4.5 ± 2.3

Mean ± SD.

DISCUSSION

The absence of significant difference among all conditions is considered to be because the knee joint function was normal because the study participants were all healthy. Kimura[12)] reported that joint position and posture sensations were related, and that joint position sensation may decrease with aging. Kiyama et al.[13)] reported that the joint position sense of young people was abnormal if the error was ≥10°; however, the average error of participants in this experiment was approximately 3°. Therefore, the position sense in this experiment is considered normal with little room for improvement in the position sense; therefore, the effect of orthosis wearing condition was small, and no significant difference was observed.

The largest error was obtained in tight force condition for both 30° and 60° flexion. According to Ramstrand et al.[14)], the joint position sense decreased when the large force was applied to fasten the brace while examining the effect of the knee brace on the joint position sense and balance in healthy participants. The pressure that the brace can attach to the knee joint has been reportedly limited, and exceeding that limit can impair the perception of joint position. Similar results were obtained in this study. A healthy knee can be harmful if overtightened. The challenge for the future is to know the specific value of this limit.

However, according to Aoki et al.[7)], the position sense of the knee joint was reportedly improved by wearing a brace in patients with severe knee OA. In addition, according to Oda et al.[15)], the effect of joint position sensation by taping has been reported. Therefore, the neurophysiological action of local compression has been reported to have an effect on joint position sense due to differences in the knee joint function and physical condition of participants, resulting in the improved joint position of patients with knee OA in the future. We would like to carry out measurements on participants with reduced position sense and verify the effect of different mounting pressures. Moreover, we would like to utilize it for the development of a flexible knee orthosis whose wearing pressure changes based on movement.

Conference presentation

Part of this research was presented at the 4th Global Conference on Biomedical Engineering & Annual Meeting of TS-BME (GCBME 2020).

Conflict of interest

There are no conflicts of interest to be disclosed in this study.

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