Patient Simulation: Handrail Position for Knee-OA Patients Considering Physical Burden and Stability

Chongyang QIU*, Shogo OKAMOTO*, Naomi YAMADA†, Yasuhiro AKIYAMA*, and Yoji YAMADA*
*Graduate School of Engineering, Nagoya University, Nagoya, Japan
†Aichi Medecal College, Kiyosu, Japan

***Abstract*—Knee pain during motions remarkably reduces the quality of life in knee osteoarthritis (OA) patients. The use of handrails can help them relieve the pain when standing up from a chair. This study investigated which handrail position such as at the affected or non-affected sides is more effective in reducing the physical burden on the impaired knee, as well as providing a better stability during a sit-to-stand (STS) motion. Healthy individuals simulated the typical STS motion of knee OA patients for avoiding the ethical concerns regarding the pain that a patient may undergo during the experiment. Results obtained from the patient simulation under controlled conditions revealed that positioning a handrail at the affected side reduces knee burden and improves stability.**

***Index Terms*—patient simulation, handrail, flexion-extension moment, COP**

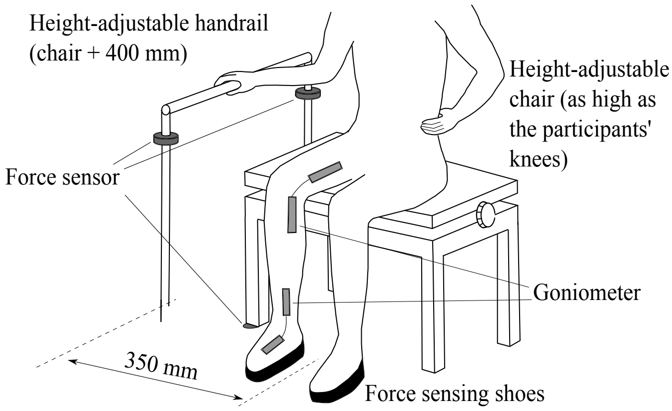

Fig. 1. Experimental setting

I. Introduction

An increasing number of patients are being affected by knee osteoarthritis (OA) in recent years. The risk of knee OA generally increases with age, and it causes pain in the affected knees during daily activities, such as STS and walking motions. Using a handrail, patients can distinctly reduce the physical burden on the impaired knee and, thus, can get relief from the pain. There have been some studies about the suitable conditions of handrail use [1], [2]; however, thus far, only a few studies have been done to investigate the distinctive effects of different handrail positions, such as at the affected or non-affected sides, in patients with unilateral knee pain. Therefore, this study investigated the effects of positioning a handrail at the side of affected-limb or non-affected-limb on STS motions. A reduction in physical burden on the affected knee and the stability during motion were adopted as the evaluation criteria. Compared with healthy people, knee OA patients adopt different postures to avoid motions that cause knee pains. However, there is an ethical issue concerning the participation of actual knee OA patients in the experiments. Because of the possibility of experiencing pain during motions, it is not ethically correct to involve knee OA patients in experiments that involve a number of knee motions under various conditions. Thus, it is of significance that healthy people simulate the typical motion of knee OA patients to provide sufficient data for developing care facilities, devices, etc. For simulating the motions of knee OA patients, Yamakawa et al. [3] utilized a pain-warning electrical stimulation wherein a change in strength according to the magnitude of knee moment was used as an indicator of the pain to obtain a more convincing patient simulation. However, they focused only on the reduction in knee burden to discuss the position of handrails, which was not sufficient to reach a comprehensive conclusion. In the present study, the stability during STS motions was also considered as a significant index.

II. Experiment

A. Participants

Two healthy male university students (participant 1: height - 173 cm, weight - 62 kg; participant 2: height - 175 cm, weight - 57 kg) participated in this study. They were not aware of the objectives of the study.

B. Apparatus

Two force sensors (PFS055YA251G6, Leptrino, Japan) were installed on the handrail to obtain the vertical handrail reaction force (vHRF). Three load cells (FX1901, TE Connectivity, USA) were placed on each shoe to measure the vertical ground reaction force (vGRF). In addition, the center of pressure (COP) on the base of support was calculated. A pressure sensitive film (FSR-406, Interlink Electronics, USA) was placed under the chair for obtaining the timing of seat-off. The experimental apparatus is shown in Fig. 1.

C. Patient Simulation

Before the main trials, the participants received short lectures on the motion of knee OA patients. Knee OA patients tend to perform a STS motion in more than 3 s due to the knee pain [4]. For reducing the physical burden on the impaired knee, additional weight (approximately 10%) can be put on

978-1-7281-0543-7/18/$31.00 ©2019 IEEE

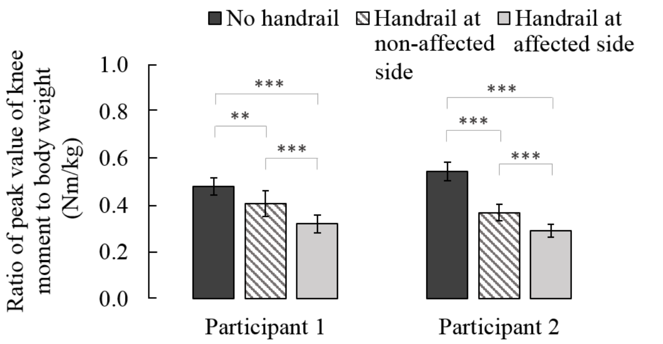

Fig. 2. Ratio of the peak value of knee extension-flexion moment to body weight. Asterisks ** and *** indicate significance levels of 0.01 and 0.001, respectively.

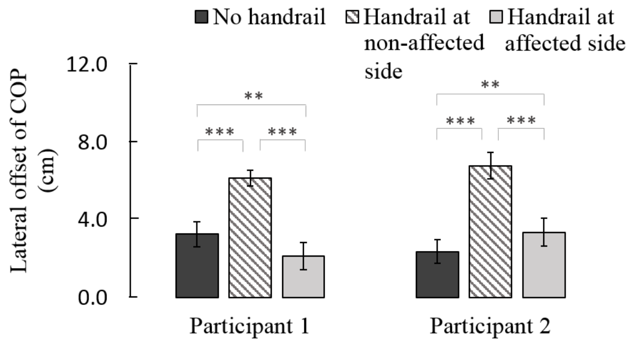

Fig. 3. Lateral offset of the COP from the center of two feet towards the handrail. For the case without the handrail, the non-affected side is the positive direction. Asterisks ** and *** indicate significance levels of 0.01 and 0.001, respectively.

the contralateral limb [4]. Moreover, a slight lateral trunk lean toward the non-affected side is typically observed during the motion. Healthy participants were informed of these features and then allowed to practice the typical motion of the patients until they became familiar.

D. Settings

Each participant sat on an adjustable chair and the seat was adjusted to the height of the participant's knee joints. The height of the handrail was set 400 mm above the seat and the distance between the handrail and center of the body was 350 mm. With respect to the distance between two feet, no restriction was set as long as it was within the width of the participant's shoulders. To reduce the influence of the arm, the hand at the no-handrail side was placed on the iliac crest.

E. Tasks

Each participant simulated the STS motions of the patient with left and right unilateral knee OA. They performed the STS motions under three conditions: without handrail; handrail positioned at the non-affected side; and handrail positioned at the affected side. For each condition, trails were repeated thirty times. Hence, a total of 180 trials (three conditions $\times$ two laterality conditions $\times$ thirty repetition) were performed by each participant.

F. Data Analysis

Under each condition, trials with the loading symmetry ratios (the ratio of the mean vGRF on the affected limb to that on the non-affected limb) beyond the range of mean $\pm$ standard deviation reported in [5] were excluded. The data of the duration between seat-off and standing position were used for the analysis. The internal flexion-extension moment working on the knee joint, which is often regarded as a reflection of burden [2], and the lateral offset of the COP, which serves as a stability index, were calculated and analyzed. Considering the small sample size, the statistical tests were conducted using each participant's data.

III. Results

As shown in Fig. 2, after using a handrail, there was a distinct reduction in the knee extension-flexion moment in both the participants. Moreover, compared with the handrail at the non-affected side, the handrail at the affected side resulted in a reduction in knee moment, indicating a lesser amount of physical burden during the STS motion (Participant 1: $t(18) = 4.23$, $p < 0.001$; Participant 2: $t(16) = 4.79$, $p < 0.001$). Regarding the lateral offset of the COP (see Fig. 3), performing a STS motion with the handrail at the non-affected side led to a significantly higher offset from the center of the two feet than that at the affected side, which resulted in a relative instability.

IV. Conclusions

This study involved simulated patients to investigate which is the effective side of positioning a handrail to reduce knee burdens and maintain stability during STS motions. After training, two participants simulated the typical STS motion of knee OA patients and consistently revealed that positioning a handrail at the affected-limb side is advantageous in terms of reducing physical burdens and maintaining stability.

References

[1] S. Kinoshita, R. Kiyama, and Y. Yoshimoto, "Effect of handrail height on sit-to-stand movement," *PloS one*, vol. 10, no. 7, p. e0133747, 2015.

[2] S. Kinoshita, "Handrail position and shape that best facilitate sit-to-stand movement," *Journal of back and musculoskeletal rehabilitation*, vol. 25, no. 1, pp. 33–45, 2012.

[3] K. Yamakawa, S. Okamoto, R. Kubo, N. Yamada, Y. Akiyama, and Y. Yamada, "Knee pain patient simulation for recommendation of sit-to-stand handrail positions," *IEEE Transactions on Human Machine Systems*, 2018.

[4] K. Turcot, S. Armand, D. Fritschy, P. Hoffmeyer, and D. Suv, "Sit-to-stand alterations in advanced knee osteoarthritis," *Gait & Posture*, vol. 36, no. 1, pp. 68–72, 2012.

[5] C. L. Christiansen and J. E. Stevens-Lapsley, "Weight-bearing asymmetry in relation to measures of impairment and functional mobility for people with knee osteoarthritis," *Archives of Physical Medicine and Rehabilitation*, vol. 91, no. 10, pp. 1524–1528, 2010.