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Original Article

Comparison of difficulty in stair ascent and descent after total knee replacement

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Abstract. [Purpose] Although many studies have shown that patients have difficulty in climbing or descending stairs after undergoing total knee replacement, no study so far has compared the difficulty of stair ascent and descent based on objective indicators. This study compared stair ascending and descending processes based on three indicators and clarified which was more difficult. [Participants and Methods] We defined 1) movement method, 2) the necessity for handrail use, and 3) speed as objective indicators. Seventy-eight patients who underwent total knee replacement participated in this study. Three months after the surgery, we examined 1) whether the patients could ascend or descend in a step-over-step or step-by-step manner, 2) whether the patients required handrail support, and measured 3) the time required to ascend and descend for four steps. [Results] The step-by-step movement and handrail requirement rates associated with stair descent were higher than the corresponding rates associated with stair ascent. In addition, the time required for stair descent was greater than that required for ascent. [Conclusion] We found that stair descent was more challenging than stair ascent in terms of all three objective indices: movement method, handrail use, and speed. The results indicate that rehabilitation after total knee replacement should focus more on stair descent than on stair ascent.

Key words: Total knee replacement, Stair ascent, Stair descent

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INTRODUCTION

Total knee replacement (TKR) is the most common treatment for end-stage knee osteoarthritis (OA), a condition that significantly reduces the quality of life[1]. TKR has led to better pain relief and a quicker return to activities of daily living after the surgery in patients with OA[2, 3]. TKR also contributes to the improvement of gait function. For example, gait speed can be restored to the same level as before surgery within 3 or 6 months after surgery[4, 5]. Therefore, TKR is considered a surgical method that provides sufficient improvement. However, Walsh et al. demonstrated that patients took twice as long to climb stairs one year following TKR surgery compared to the control group, and 30% of these patients could climb the stairs step-by-step[6]. Even after two years, 60% of patients still required handrails when climbing stairs[7]. For post-TKR patients, the ability to ascend and descend stairs significantly contributes to patients' level of satisfaction with the surgery[8], suggesting that regaining the ability to climb up and down the stairs is essential for these patients. For post-TKR patients,

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regaining the ability to climb up and down the stairs is also essential, because such ability significantly contributes to their level of satisfaction after the surgery.

A study using a questionnaire survey to assess stair ascent and descent in patients who had undergone a TKR found that 27% of patients felt limited during stair ascent, while an even more significant percentage (65%) felt during stair descent[9]. In clinical practice, stair descent is generally considered more difficult than stair ascent. However, no study has objectively examined the difference in perceived difficulty between stair ascent and descent in postoperative patients. Elucidating the difference in difficulty is crucial for determining the treatment for stair ascent and descent in patients who have undergone a TKR.

The difficulty in climbing stairs can be evaluated through the following methods: (1) Movement method; determining whether the participant can climb step-over-step or step-by-step[9], (2) Use of handrail; determining whether the participant requires handrail support[10], and (3) Speed; measuring the time required to climb up or down a fixed number of steps[11]. Therefore, in this study, we defined the movement method, handrail support, and speed as objective indicators of the difficulty in ascending and descending the stairs, and evaluated which was more difficult for post TKR patients.

PARTICIPANTS AND METHODS

The study participants consisted of patients diagnosed with medial knee osteoarthritis at our hospital. They underwent a unilateral TKR from April 2018 to July 2019 and were able to ascend and descend the stairs under supervision at 3 months after the surgery. Patients with orthopedic or neurological disorders that interfered with stair ascent and descent irrespective of TKR and patients who underwent TKR on the contralateral knee within 1 year after the surgery were excluded.

Written informed consent was obtained from all the participants. This study was carried out with the approval of the Ethics Review Board of Shimada Hospital (approval number: 2018-003) and the Ethics Review Board of the School of Comprehensive Rehabilitation, Osaka Prefecture University (approval number: 2018-110).

We assessed the stair-climbing ability (movement method, handrail, speed) separately for stair ascent and descent. We used the stairs consisting of four steps, and each step had a height of 18 cm with a tread surface of 25 cm. Regarding the movement method and use of a handrail, each patient was asked to select one of the following three options for both stair ascent and descent: (1) climb step-over-step without using the handrail, (2) climb step-over-step while using the handrail, and (3) climb step-by-step while using the handrail. Before making their selection, several practice sessions were conducted to determine the participants' preferred movement method. During these sessions, when participants inquired about which handrail to use, left or right, we informed them that either was acceptable. We recorded the movement method and handrail use.

The speed of stair ascent and descent was measured for one of the movement methods selected by the patient. First, the patient was instructed to stand with both feet aligned in front of the stairs for assessing both stair ascent and descent. Following this, the patient was verbally instructed to ascend or descend the stairs at the usual speed and stand with the feet aligned when they reached the top or bottom of the stairs. We used a high-speed camera (EX-FC400S; CASIO, Tokyo, Japan) to shoot at a frame rate of 240 fps from a location where the participant's feet could be observed. We measured the required time from heel takeoff at the start to the ground contact of the sole at the end of the task using the video for both stair ascent and descent. The process was performed twice, and the shortest measured time was retained.

In the statistical analysis, Fisher's exact test was used to compare the use of handrails and the movement method between stair ascent and stair descent. The required time between stair ascent and descent was compared using the paired t-test. We used the SPSS Statistics 26 (IBM Corp., Armonk, NY, USA) software for statistical analyses, and statistical significance was set at $p<0.05$.

RESULTS

Of the total 78 participants, 15 were males, and 63 were females. Table 1 presents the basic characteristics of the participants.

A comparison of the stair-climbing ability between ascending and descending stairs is shown in Table 2. With regard to the movement method, a significantly greater number of patients employed the step-by-step method during stair descent than during ascent ($p<0.01$). A significantly greater number of patients used handrail support during stair descent than during stair ascent ($p<0.01$). Furthermore, the duration of stair descent was more prolonged than stair ascent ($p<0.01$).

DISCUSSION

In this study, we compared and examined stair ascent and descent in post-TKR patients from the following perspectives: movement method, use of handrail, and speed. Consequently, we clarified that stair descent was more difficult than stair ascent from all perspectives.

The difference in difficulty between stair ascent and descent could be attributed mainly to the three factors. First, the contraction patterns of the knee extensor muscles are different between stair ascent and descent. The body's center of gravity

Table 1. Characteristics of study participants

Post-operative days	90.4 ± 8.7
Age (years)	75.1 ± 6.1
Gender (male/female)	15/63
Height (m)	1.53 ± 0.07
Weight (kg)	61.9 ± 11.4
Body mass index (kg/m^2)	26.3 ± 4.6

Values presented as mean ± standard deviation.

Table 2. Comparison of descending and ascending the stairs (n=78)

	Descending	Ascending
Stair climbing time (sec)[a*]	5.1 ± 1.7	4.4 ± 1.1
Handrail use (people [%])[b*]	56 [72]	37 [47]
Step-by-step (people [%])[b*]	34 [44]	8 [10]

[a]Mean ± standard deviation are displayed using a paired t-test.
[b]Fisher's exact test was used.
*p<0.01.

shifts upward during stair ascent, while the opposite is true during stair descent. This means that the knee extensor muscles employ concentric contraction patterns during stair ascent. In contrast, these muscles utilize an eccentric contraction pattern to control the acceleration of the body due to shifts in the center of gravity during stair descent[12]. Eccentric contraction is a complex movement that requires adjustment of muscle contraction by the descending tracts of the upper central nervous system through the feedback of type Ib afferent feedback from Golgi organs[13]. Patients underwent TKR surgery are less proficient at controlling eccentric contractions than healthy controls[14]. It is likely that many patients have difficulty during stair descent due to eccentric contraction, in contrast to the smoother stair ascent facilitated by concentric contraction.

Second, the co-contraction of the knee extensor and flexor muscles is different between stair ascent and descent. Excessive co-contractions of the knee extensor and flexor muscles during walking were observed in patients who underwent a TKR[15]. Compared to young individuals, older adults were found to experience greater co-contraction of the knee extensor and flexor muscles during stair descent[16]. The findings from these studies suggest that patients with TKR experience excessive co-contraction during stair descent. Excessive co-contraction leads to a decrease in the smoothness of the movement. The smoothness of center of gravity movement, which can be evaluated by jerk value[17–19], decreases with age in stair descent rather than stair ascent[18]. Based on the above findings, it was inferred that increased co-contractions impair smooth knee flexion and make stair descent challenging in patients with TKR.

Finally, the difficulty of compensation for the knee joint by other joints is different between stair ascent and descent. Stair ascent in patients with TKR had a significantly lower knee joint extension momentum than the control group[20]. It could be attributed to compensatory movements by other joints during the stair ascent. The hip joint extension momentum exerted a higher contribution during stair ascent[21], and stair ascent in patients with TKR required a significantly higher hip extension momentum than in the control group[22]. These findings support the fact that the load on the knee joint is reduced by the compensatory use of the hip joint during stair ascent.

Conversely, during stair descent, it is reported that there is no difference in knee joint extension momentum between older adults and young individuals[23], and healthy older adults require a similar knee joint extension momentum to patients having undergone a TKR[9]. Overall, patients with TKR cannot compensate for knee joint movement by other joints during stair descent, while in comparison, they can compensate for knee joint movement during stair ascent. Based on these reports, it is inferred that more patients complained of difficulty in stair descent than in stair ascent because it is challenging to use compensatory movements, and the load on the knee joint cannot be reduced.

There are also some limitations to this study. Firstly, a control group comprising a healthy elderly population was not established in the present study. The primary reason is that the study was conducted in a hospital setting, making it challenging to form a control group. A previous study involving 664 community-dwelling older individuals found that the speed of ascending and descending stairs was similar (1.6 steps/s ascending, 1.7 steps/s descending) and that the percentage of people using handrails did not differ greatly (45% ascending, 52% descending)[24]. In contrast, our present study revealed that patients descended stairs more slowly than they ascended them, with a higher proportion needing to use a handrail when descending. These findings suggest that difficulty in descending stairs may be one of the characteristics of TKR patients. However, further studies are needed with healthy older individuals as a control group. Secondly, the stairs only had four steps in this study. It is possible that the participants did not reach a steady state during stair ascent and descent assessments. Further research is needed using more number of stairs to account for the stabilization of walking pattern. Finally, we did not measure biomechanical variables such as joint angles and muscle activation patterns during the stair ascent and descent. Therefore, we could not clarify why patients who underwent a TKR experienced greater difficulty during stair descent than during stair ascent. Future studies are required to ascertain the cause of the greater difficulty experienced by patients during stair descent.

In conclusion, our observations suggest that patients encounter more difficulty descending than ascending stairs. This difficulty, previously reported mainly through questionnaires and personal experiences, was validated in this study using three objective measures: movement method, handrails, and time. These findings highlight the need to implement rehabilitation programs focused on acquiring stair descent skills, which may contribute to increased patient satisfaction.

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Conflicts of interest

The authors declare no conflict of interest.

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