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Case Study

Effect of heel lift insertion on gait function in a patient with total hip arthroplasty with patient-perceived leg length difference: a case report

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Abstract. [Purpose] The effect of heel lift insertion on gait in patients who have undergone total hip arthroplasty (THA) with patient-perceived leg length difference is seldom referenced in the literature. We used an AB design to investigate the alterations of gait function before and after inserting a heel lift on the non-operative side. [Participant and Methods] The participant had a patient-perceived leg length difference after THA and presented with gait disturbance. The survey phase was 10 days (phase A: normal physiotherapy for five days, and phase B: normal physiotherapy and heel lift insertion for another five days) from the 17th day following THA. The ambulatory task was conducted at a self-determined, comfortable pace and objectively assessed using an inertial sensor. [Results] The insertion of a heel lift partially improved the gait symmetry and the ratio of lumbar acceleration in three directions; it also corrected the patient-perceived leg length difference. [Conclusion] An investigation was carried out to examine the impact of a heel lift on gait in a single case of THA with patient-reported leg length difference. The application of a heel lift may enhance the relationship between the patient-perceived leg length difference, gait symmetry, and the ratio of lumbar acceleration in three dimensions.

Key words: Total hip arthroplasty, Patient-perceived leg length difference, Heel lift

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INTRODUCTION

Total hip arthroplasty (THA) improves quality of life[1–3], physical function[2], and gait function[4]. However, the gait function of healthy individuals is not reached in the long term after THA[5]. In addition, patient-perceived leg length difference (Perception of elongation in the operative limb) has been reported to persist in 8–44% of patients following THA[6–9]. Patient-perceived leg length difference reduces physical function, satisfaction[6], gait speed, stride length, and gait symmetry[10]. Among THA patients with patient-perceived leg length difference, a significant proportion (52–64%) exhibit leg length difference of 5 mm or less[8, 9]. It is worth noting that factors other than surgical leg extension may also contribute to these patient-perceived leg length difference. Patient-perceived leg length difference is associated with pelvic tilt in the frontal plane[11], hip extension during gait, and adduction range of motion[10], notable points for correcting patient-perceived leg length difference. Patient-perceived leg length difference 3 months after THA is a risk factor for patient-perceived leg length difference 1 year after THA[7]. Immediately following THA, it is necessary to intervene during physiotherapy to correct

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patient-perceived leg length difference. Previous literature reveals that patient-perceived leg length difference may promote abnormal pelvic and lumbar spine movements during gait after THA compared to healthy individuals[12, 13]. Inserting a heel lift early after THA can improve patient-perceived leg length difference[14], but its mechanism and effect on gait are unknown.

It is possible to quantify gait function from the acceleration component of the lumbar spine using inertial measurement units, which are easily measured in clinical practice[15, 16]. Rapp et al.[17] reported that gait symmetry in patients after THA was lower than in healthy individuals in the vertical direction of lumbar acceleration. Wada et al.[18] reported that after THA, vertical, mediolateral, and anteroposterior direction ratios of lumbar acceleration during walking were closer to healthy individuals than before THA.

We had the opportunity to insert a heel lift in a case with patient-perceived leg length difference after THA. In a single case study using an AB design, we investigated whether the insertion of a heel lift is useful for improving gait ability. This case report was prepared according to the consensus-based single-case reporting guideline in behavioural interventions (SCRIBE).

PARTICIPANTS AND METHODS

A 69-year-old female had received a diagnosis of right hip osteoarthritis two years prior to undergoing THA. Conservative outpatient treatment was administered; however, the symptoms failed to ameliorate, prompting the implementation of THA. The main complaints before THA were pain and gait disturbance and the level of T-cane independence. Before THA, the right hip joint exhibited constrained range of motion (flexion: 70°, extension: −40°, abduction: 10°) and muscular weakness (Manual Muscle Test: flexion −grade 4, abduction −grade 2). Lameness was prominent, and long-distance gait was difficult. There is no patient-perceived leg length difference, no history of orthopaedic disease, and no accompanying symptoms, such as pain in other anatomical regions. According to the hospital protocol, gait practice was started early postoperatively. There was patient-perceived leg length difference after the start of gait practice, and her physician prescribed a heel lift. The participant read and signed an informed consent form. This study was approved by the Ethics Committee of the University (study number: F200026).

Radiographic measurements before and after THA are shown in Fig. 1. Pelvic tilt angles in the frontal plane and leg length difference are shown in Table 1. The bodily orientation for diagnostic imaging was the dorsal recumbent position. The pelvis on the operated side was lowered before and after the operation. Leg length difference was shortened on the operation side before the operation, and leg extension was performed by operation. Leg length difference was measured as the vertical distance between the most prominent point of the lesser trochanter and trans-teardrop line in units of 0.01 mm[19]. Pelvic tilt angle in the frontal plane was measured as the subtended angle between the horizon and trans-teardrop line in units of 1°. SYNAPSE SCOPE (FUJIFILM, Tokyo, Japan) was used for measurement.

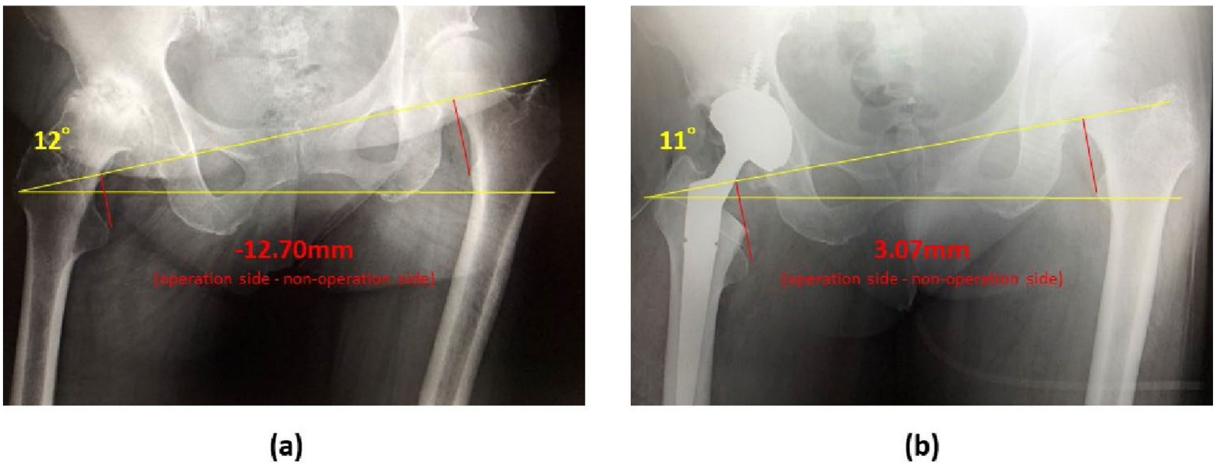

Fig. 1. Frontal radiographs.
(a) Pre-operation (b) Post-operation.

Table 1. Pelvic tilt angles in the frontal plane and leg length difference by radiographic measurements

	Pelvic tilt angle in the frontal plane (°)[a]	Leg length difference (mm)[b]
Pre-operation	12	−12.70
Post-operation	11	3.07

[a]Positive values represent tilt towards the operation side, negative values represent tilt towards the non-operation side.
[b]Positive values mean that the operation side is longer, negative values mean that the operation side is shorter.

The block was used to measure patient-perceived leg length difference[20], and a 2 mm plate was gradually inserted into the sole on the non-operation side to measure the height at which the patient's sense of leg length difference disappeared. Both upper limbs were placed in the drooping position, and measurements were taken in a standing position with the legs open at a distance between the anterior superior iliac spines.

The participant walked wearing flat shoes at a self-selected comfortable speed, and measurements were taken twice on a gait path of 11 meters. The measurement was performed with the heel lift removed every day from 5 to 6 pm after gait about 50 meters. Gait speed [m/s], stride length [m], and cadence [steps/min] were calculated from gait time and the number of steps in the middle 5 meters. In addition, inertial measurement units (Sports sensing, Fukuoka, Japan) were used to obtain acceleration (sample frequency=1,000 Hz). Inertial measurement units were attached via elastic straps to the dorsum of the posterior surface of the fourth and fifth lumbar vertebra. The acceleration data were filtered using low-pass filters with 1,000 Hz frequency. Timepoint of heel contact was identified from the acceleration of the vertical component[17]. Before measurement, the participant maintained a standing position during the 4 seconds required to conduct revisions and calibration of the accelerometer gravitation. The central five gait cycles were measured twice, and acceleration data for a total of 10 gait cycles were extracted. From the acceleration components, vertical direction autocorrelation[15] and root mean square ratio[16] in three directions were calculated. Autocorrelation is an index of gait symmetry when calculated in consecutive steps (Autocorrelation-1) and an index of gait regularity when calculated in continuous stride (Autocorrelation-2). Autocorrelation is expressed on a scale of 0 to 1, where a low value indicates poor gait symmetry and regularity. The acceleration signal underwent temporal normalization, where each step was depicted by 100 data points, and a total of 2,000 data points were used for computing autocorrelation. In addition, the root mean square in three directions was calculated. This parameter indicates the magnitude of acceleration[16, 21], as the root mean square ratio is computed from the root mean square values in three directions, which allows for the elimination of the influence of gait speed[16]. Wada et al.[18] reported that the root mean square ratio of healthy individuals was 0.69 in the vertical direction, 0.41 in the mediolateral, and 0.59 in the anteroposterior. We will regard this value as fitting for our assessment.

The investigation commenced 17 days post THA, once it was ascertained that the patient could maintain stable ambulation, covering a distance of more than 11 meters (gait distance during measurement), employing a T-shaped cane for support. The study persisted for a duration of 10 days. The investigation used an AB design containing two phases (Phase A: normal physiotherapy for 5 days, phase B: normal physiotherapy and heel lift insertion for 5 days) (Fig. 2). The patient initially perceived a leg length difference of 20 mm. however, the perceived leg length difference diminishes during the early postoperative phase[7]. Additionally, given the radiographic leg length difference as 3 mm, the attending physician recommended a 10 mm heel lift. This patient was instructed to always use shoes with the heel lift inserted when moving.

The physiotherapy program encompassed range of motion exercises and muscle strengthening exercises targeting the right hip joint, postural alignment, and gait exercises and was carried out for about 60 minutes daily. The intensity of muscle strengthening training was gradually modulated based on pain perception, while postural correction involved elevating the pelvic girdle on the operation side, with the goal of achieving pelvic girdle alignment.

A slope, indicating the progress of each phase, was calculated using the median values of the first and second half of the experiment. The change in slope was visually judged. Furthermore, we investigated the improvement in phase B using a binomial test based on the slope of phase A. Statistical significance was set at $p<0.05$.

RESULTS

There were no adverse events observed, such as exacerbation of pain or incidents of falls, throughout the entire duration of the intervention. Figure 3 shows the progress of each evaluation result, and Table 2 shows the slopes of both phases and the result of the binomial test. Gait speed, stride length, and cadence showed gradual improvement, but no significant change was observed in each phase. Autocorrelation-1 showed greater improvement in phase B than phase A, and a significant difference was observed in the binomial test ($p<0.05$). Autocorrelation-2 showed greater improvement in phase A than in phase B from the slope in both phases. Root mean square ratio were closer to those of healthy subjects in phase B than in phase A for all components from the slopes of both phases. Patient-perceived leg length difference was improved in phase B, and a significant difference was observed in the binomial test ($p<0.05$).

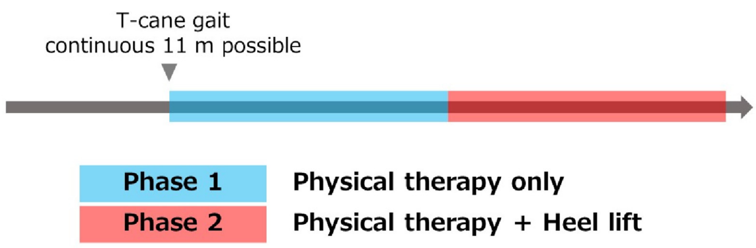

Fig. 2. Outline of this investigation (AB design).

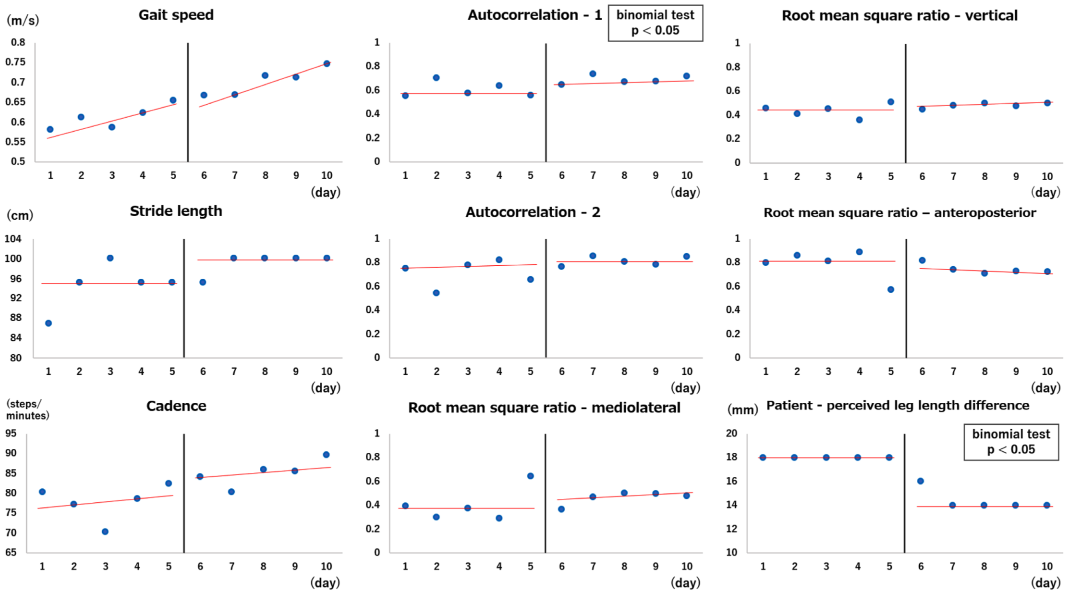

Fig. 3. Progress during each gait evaluation and patient-perceived leg length difference.

Table 2. The slopes of both phases and the results of the binomial test

	Phase A - slope	Phase B - slope	Significance
Gait speed	0.019	0.024	
Stride length	0.000	0.000	
Cadence	0.699	0.955	
Autocorrelation-1	0.000	0.002	*
Autocorrelation-2	0.015	0.000	
Root mean square ratio-mediolateral	0.000	0.014	
Root mean square ratio-vertical	0.000	0.007	
Root mean square ratio-anteroposterior	0.000	−0.008	
Patient-perceived leg length difference	0.000	0.000	*

*p<0.05.
Autocorrelation-1 is an index of gait symmetry calculated in consecutive steps.
Autocorrelation-2 is an index of gait symmetry calculated in continuous stride.

DISCUSSION

In this study, we investigated whether the insertion of a heel lift on the non-operation side was useful in improving gait ability in a THA patient with patient-perceived leg length difference. Insertion of a heel lift on the non-operation side corrected patient-perceived leg length difference, improved gait symmetry, and optimized movement of the lumbar spine. Spatiotemporal parameters and gait regularity were improved without the heel lift.

Autocorrelation-1 and root mean square ratio did not improve in phase A but did in phase B, likely due to the heel lift on the non-operation side. In addition, patient-perceived leg length difference did not improve in phase A but did in phase B, supporting the finding of a previous study[14]. Since patient-perceived leg length difference is associated with pelvic tilt and asymmetry of knee joint flexion angle[11], insertion of a heel lift may have improved these alignments. The difference in the vertical distance from the floor to the hip joint caused by pelvic tilt is adjusted by increasing knee joint flexion angle on the sides of the inferior pelvic. Increasing knee flexion angle may shift the position of the knee joint on the sagittal plane anteriorly and increase the distance between the knee joint and the floor reaction force. The distance between the knee joint and the floor reaction force on the sagittal plane is related to knee joint flexion moment[22], and the load on lower limb muscles increases (Fig. 4). During this patient's physical therapy, it was important to reduce load on lower limb muscles on the operation side, due to correction of pelvic tilt and knee flexion on that side. It is possible that the hip abductor muscles may experience increased ease of elongation when reducing the load on lower limb muscles during standing. The improvement in patient-perceived leg length difference from phase B is due to the knee joint on the operation side being extended by insertion

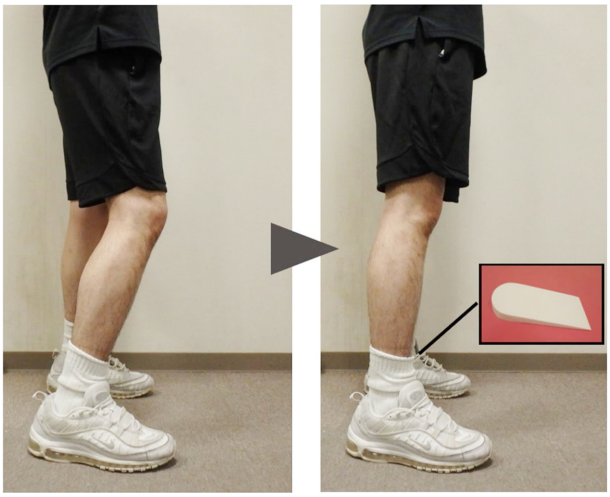

Fig. 4. Alterations in lower limb alignment resulting from the introduction of a heel lift.
The heel lift on the non-operation side reduces the difference in the vertical distance from the floor to the hip joint caused by pelvic tilt, thereby reducing knee joint flexion angle on the operation side. Decreasing knee flexion angle may shift the position of the knee joint on the sagittal plane posteriorly and reducing the distance between the knee joint and the floor reaction force. This reduces the flexion moment of the knee joint on the operation side and may reduce the load on lower limb muscles on that side. This photograph does not pertain to the patient.

of the heel lift on the non-operation side, which reduced the load on hip abductor muscles on the operation side contributed to improved extensibility. Improving the extensibility of the hip abductor muscles on the operation side may contribute to correcting the pelvic tilt. Therefore, improved gait ability from phase B may be associated with improved patient-perceived leg length difference. Gait symmetry of the vertical component of lumbar acceleration was improved from phase B. The presence of leg length difference increases the amount of vertical movement in the body's center of gravity during gait[23] due to characteristics of gait in which left and right leg support periods are repeated alternately and decrease gait symmetry. Therefore, it is considered that gait symmetry was improved due to the reduction of pelvic tilt with the correction of patient-perceived leg length difference.

Root mean square ratio increased in the vertical and mediolateral directions and decreased in the anteroposterior direction decreased from phase B. Therefore, vertical and anteroposterior directions approached reference values in this patient, and mediolateral direction increased slightly. Root mean square values were all decreased. Since root mean square ratio is in three directions, the vertical and mediolateral ratios increased relatively with a large decrease in the anteroposterior direction. Post-THA gait has been reported to increase pelvic anteversion during the stance phase[24], affecting lumbar spine movement on the sagittal plane. Furthermore, patient-perceived leg length difference reduces hip extension angle during the stance phase[10], and the effect on the lumbar spine is greater. Acceleration in the anteroposterior direction decreased significantly with the correction of patient-perceived leg length difference, and root mean square ratio in vertical and anteroposterior directions approached the reference values. Therefore, it is possible that gait function, which shows improvement from phase B, is due to the correction of patient-perceived leg length difference. However, since root mean square ratio in mediolateral shows a slightly high value, the movement of the lumbar spine on the frontal plane increased. These enhancements were observed following the removal of the heel lift, thus suggesting the potential acquisition of a motor learning effect. In addition, this patient felt easier to move with the heel lift on the non-operation side inserted.

Gait speed, stride length, cadence, and Autocorrelation-2 improved from phase A through natural course and physiotherapy intervention. Gait regularity is associated with fall risk[25]. Rapp et al.[17] reported that Autocorrelation-2 for 15–27 days after THA was 0.90–0.91. Autocorrelation-2 in this patient had an average of 0.76 for 10 days but showed gradual improvement, suggesting that the risk of falls was reduced from phase A.

This study investigated the effect of heel lift on the non-operation side insertion on gait ability in a THA patient with patient-perceived leg length difference. Spatiotemporal parameters and gait regularity were improved by natural course and physical therapy. The insertion of a heel lift on the non-operation side partially improved gait symmetry and the ratio of lumbar acceleration in three directions. Limitations of this study include a short intervention phase, and that phase A was not investigated again. In addition, the results from this study only show data from an early postoperative intervention. In other words, one must interpret the outcomes of this investigation with due consideration for the fact that it is a period during which the conventional postoperative convalescence is anticipated to be substantial. Furthermore, it is deemed that the upright stance is more favorable as the designated location for capturing radiographic measurements. However, it must be acknowledged that the research is also constrained by the utilization of the supine position for the measurements.

This study investigated the effect of heel lift insertion on gait ability in a THA patient with patient-perceived leg length difference. Spatiotemporal parameters and gait regularity were improved by natural course and physical therapy. The insertion of a heel lift partially improved gait symmetry and the ratio of lumbar acceleration in three directions.

Conflict of interest

There are no conflicts of interest to declare.

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