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PHYSICAL THERAPY RESEARCH

SCIENTIFIC RESEARCH ARTICLE (ORIGINAL ARTICLE)

The Effectiveness of Specific Exercise Approach or Modifiable Heel Lift in the Treatment of Functional Leg Length Discrepancy in Early Post-surgery Inpatients after Total Hip Arthroplasty: A Randomized Controlled Trial with a PROBE design

Tatsuya NAKANOWATARI, PhD, PT[1,2], Yoshimi SUZUKAMO, PhD[1] and Shin-Ichi IZUMI, PhD, MD[1,3]

[1)] *Department of Physical Medicine and Rehabilitation, Tohoku University Graduate School of Medicine*
[2)] *Department of Physical Therapy, Yamagata Prefectural University of Health Sciences*
[3)] *Department of Physical Medicine and Rehabilitation, Tohoku University Graduate School of Biomedical Engineering*

ABSTRACT. Objective: This study investigated the effectiveness of a specific exercise approach (SEA) or modifiable heel lift (MHL) to improve functional leg length discrepancy (LLD) after total hip arthroplasty (THA). Methods: The study was a randomized controlled trial with a PROBE (prospective, randomized, open, blinded-endpoint) design trial. Patients (n=33) with both functional and perceived LLDs, 1 week after THA, were randomized to the SEA, MHL, or control groups. Patients in the SEA group performed 2 weeks of exercises to improve hip contracture and lumbar scoliosis. Patients in the MHL group used an insole-type heel lift to correct functional LLD. The control group received normal postoperative care, comprising standard rehabilitation after THA. The primary outcomes were functional LLD, measured by a block test, and patient-perceived LLD at 3 weeks after the surgery. Secondary outcomes included the visual analog scale (VAS) for pain, the Timed Up and Go (TUG) test, and the Western Ontario and McMaster Universities Osteoarthritis index (WOMAC) at 3 weeks after the surgery. Results: The functional LLDs (mean ± SD) for the SEA (3.3 ± 3.1 mm) and MHL (2.2 ± 2.1 mm) groups were significantly smaller than for the control group (6.4 ± 4.0 mm). The degree of patient-perceived LLD differed significantly between the SEA and the control groups (p=.005). Conclusions: SEA and MHL use, during early post-operative recovery, can produce relevant changes in functional LLD after THA.

Key words: Functional leg length discrepancy, Total hip arthroplasty, therapeutic exercise, Heel lift, Randomized controlled trial

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Patient-perceived leg length discrepancy (LLD) after total hip arthroplasty (THA) has important implications on quality of life[1,2)], function[3)] and satisfaction[3,4)]. Physical LLD can be divided into 2 etiological groups: structural LLD, defined as those who are associated with shortening of bony structures, and functional LLD, defined as those who are the result of altered mechanics of the lower extremities[5,6)]. Nakanowatari *et al.*[7)] found that the patient-perceived LLD was more associated with functional LLD and that patients with functional LLD 3 weeks after THA had poorer physical performance at 2 months than patients with structural LLD alone. Therefore, these findings suggest that early postoperative therapeutic interventions for functional LLD could be important for improving the patient-perceived LLD and functional outcomes after THA.

Functional LLD is caused by abduction or adduction contracture of the hip joint and lumbar scoliosis resulting in pelvic obliquity[8,9)]. Therefore, therapeutic exercise approach to hip contracture and lumbar scoliosis could be effective in

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Correspondence to: Tatsuya Nakanowatari, Department of Physical Therapy, Yamagata Prefectural University of Health Sciences, 260 Kamiyanagi, Yamagata-City, Yamagata 990-2212, Japan
e-mail: tnakanowatari@yachts.ac.jp

improving functional LLD. Sobiech *et al.*[10] recently have been reported that exercises involving post-isometric relaxation techniques for hip flexors and abductors aided in eliminating patient-perceived LLD. Additionally, the use of orthotics for functional LLD can improve symmetry in the gait[11] and reduce lower back pain and functional disability[12], although orthotics such as a heel lift has been not recommended until soft tissue has recovered[13]. Nishijima *et al.*[14] have been reported that functional LLD decreased by use of modifiable heel lift in the early postoperative stage. From this previous study, if the height of heel lift is modifiable, heel lift use in the early postoperative stage can't have so much compensatory as facilitative for functional LLD recovery. We also consider that a continuing condition without correction of functional LLD could inhibit the recovery of the hip contracture because the knee was often flexed while the pelvis was tilted downward on the affected side as a result of the shortening of the lateral and or anterior hip muscles.

Based on recent studies, it is possible to hypothesize that both therapeutic exercise approach and modifiable heel lift can be effective at improving functional LLD. However, there are no studies demonstrating the effectiveness of exercise approach and orthotics as a heel lift to improve functional LLD with a randomized control trial (RCT) including a control group. Because the effectiveness of both therapeutic exercise approach and modifiable heel lift to improve functional LLD has have not been clarified, it is necessary to individually determine about both interventions. Therefore, this study focused on whether there are the effectiveness on therapeutic exercise approach or modifiable heel lift for improving functional LLD after THA.

The purpose of this study was to determine whether the addition of an exercise approach or heel lift to the early postoperative rehabilitation program could improve functional LLD, patient-perceived LLD, and other functional outcomes more than standard rehabilitation alone in the short term after THA.

Methods

Experimental design

The study design was a two-interventions, 3 parallel groups, randomized controlled trial with a PROBE (prospective, randomized, open, blinded-endpoint) design. The protocol was approved by the ethical committee of the Tohoku University Hospital. The study was conducted between February and July 2013, following the ethical guidelines of the Declaration of Helsinki. This trial was registered with the UMIN Clinical Trials Registry, number UMIN000009095.

Patients

The subject population included 1 week postoperative patients who underwent primary unilateral THA with diagnosed osteoarthritis of the hip at a general hospital in Japan. Inclusion criteria were (1) elective THA, (2) younger than 80 years old, (3) the standard postoperative program in which patients start full-weight bearing on the operated limb the day after surgery and are discharged at 3 weeks, (4) height of 2.5 mm or higher on the functional LLD measured by a block test, and (5) presence of patient-perceived LLD (the operative leg lengthening).

Exclusion criteria were (1) revision of THA, (2) weight greater than 100 kg, (3) THA by a direct anterior approach, (4) inadequate cognitive functioning, (5) a scale of less than class 3 on the American Society of Anesthesiologist physical status, and (6) diagnosed with rheumatoid, psychological, or neurological disease.

Within 1 week of the surgery, patients were checked for inclusion and exclusion criteria by a physical therapist and asked to sign informed consent form by a research manager. After baseline measurements were taken (t0), participants were randomly assigned to 2 intervention groups or the control group by drawing labels ort of an envelope. Labels numbered 1 (n=5), 2 (n=5) or 3 (n=5) were placed into sealed opaque envelope by a research assistant not associated with the patient enrollment, the interventions, and outcome assessment to ensure the concealment of the allocation. Once a label was drawn and the subjects assigned, the label was not placed back into the envelope until all labels (n=15) were drawn. Physical therapists performed the training and the patients were not blinded to treatment allocations, although the outcome assessor was blinded to treatment allocations. The patients received the interventions and normal rehabilitation mainly from same attending physical therapist from before the allocation. The physical therapists who have charge of patients after THA were instructed about the study interventions in advance.

Interventions

There were 2 intervention groups: the specific exercise approach (SEA) group and the modifiable heel lift (MHL) group. The protocols of the 2 interventions were provided by the research manager along with a written manual to ensure a standardized approach. The SEA and MHL interventions were administered by individual clinical physical therapists (n=8).

SEA consisted of semi-structured techniques to treat contractures that resulted in functional LLD. The techniques included post-isometric muscle relaxation (manually resisted isometric contraction followed by relaxation)[15] and side shift and hitch exercises for scoliosis[16]. The post-isometric muscle relaxation focused on hip joint flexors and abductors of the leg lengthening side, which commonly result in pelvic obliquity. The side shift exercise included in this approach, involves shifting of the lateral trunk to the concavity of the scoliosis in the lumber spine. In the hitch

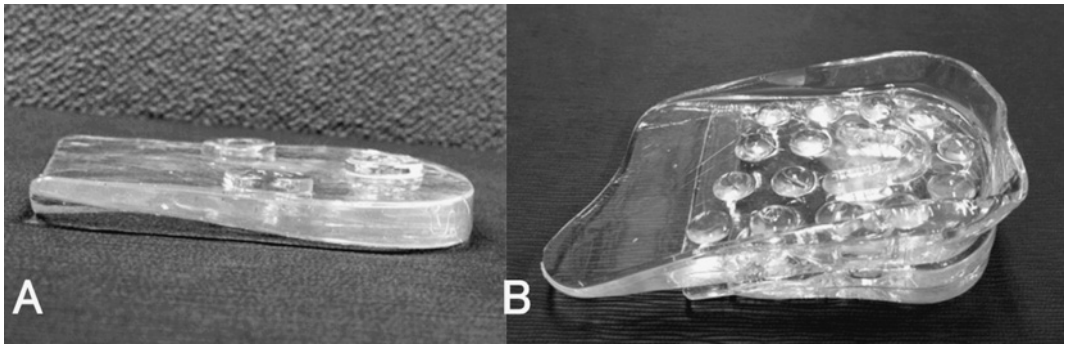

Figure 1. The modifiable heel lift (MHL).
(A) A single 5-mm-high heel lift. (B) Three heel lifts, 15-mm high.

exercise, patients lifted their heel on the obliquity side of their pelvis while keeping their hip and knee straight. During physical therapy sessions, patients received SEA once a day until discharged. The protocol provided guidance on exercise prescription and progression, nevertheless could be tailored to the findings of the physical assessment of individual patients.

Patients in the MHL group were given an insole-type heel lift to correct the functional LLD, made of a thermo plastic rubber (Como Life Company Ltd., Japan) of 5-mm thickness to put inside the shoe of the "shorter" leg (Fig. 1). The size and shape of the heel lift insert was common in all patients. The height of the heel lift insert was adjusted gradually. The initial height at baseline was set based on functional LLD. Depressions of 5 mm each were made by the physical therapist as soon as functional LLD was changed. This was continued until the functional LLD was eliminated. Patients were then asked to wear the heel lift insert all day until at least the day of discharge. All patients were instructed to notify us if they wished to withdraw from experiment.

Patients in the control group received normal rehabilitation in the hospital, which consisted of individually supervised sessions with a physical therapist once a day during the hospital stay. In these sessions patients received a range of motion and strengthening exercises, and training activities such as sit-to-stand, walking, and stair climbing. Patients in the SEA and MHL groups also received these components.

Measurements

Baseline measurements (t0) were taken 1 week after the surgery and the second measurements were taken 3 weeks after the surgery at discharge (t1). At the time of baseline measurements, demographic data (Table 1) were verified.

Primary outcomes measures were the functional LLD and patient-perceived LLD at t0 and t1. Functional LLD was measured by a block test[6,17], where the patient was asked to stand with an adjustable lift under the shorter leg until it was determined that the leg length was corrected (using patient's response that equalized his or her leg length inequality and assessment of knee joint angle). It has been proposed that this method takes into account the disparity in foot height between the two legs entailed in the pelvic obliquity and also aids in determining the functional LLD by using varying heights of the blocks to establish the additional length required for the patient feel level[17]. The inter-rater reliability ($ICC_{1,2}$=0.88-0.96, kappa coefficient=0.91) of this measurement was high[18]. It has also been reported that there were no significant difference in subject's perceptions obtained on repeated block tests[19]. In cases of structural LLD, the blocks under the shorter leg (affected side) correct compensatory pelvic obliquity that results from the deformity of structural components. Meanwhile, in cases of functional LLD, the blocks under the shorter leg (unaffected side) equalize secondary leg lengthening that derives from muscle of joint tightness across hip joint or spine resulting in the pelvic obliquity[6] (Fig. 2). The block height was then measured in increments of 2.5 mm. In assessing block test, patients stood barefoot in a natural and relaxed position with their arms by their sides. The feet were placed with apart at a comfortable distance and with pain-free weight-bearing on the operated leg. Patients with patient-perceived LLD were asked to fill out a questionnaire, which included the degrees (assessed with a 5-point scale from no inequality to unbearable inequality) of LLD. Based on previous studies[1-3,7,20], the responses of Questionnaire about LLD was defined as patient-perceived LLD.

Secondary outcome measures were determined by the visual analog scale (VAS)[21] for pain in the operated hip at rest, the Japanese version of the Western Ontario and McMaster Universities osteoarthritis index (WOMAC)[22,23] subscale pain and function, and the Timed Up and Go (TUG) test[24] at t0 and t1. It has been reported that patient-perceived LLD was associated with poor health-related quality of life like WOMAC[1,2] and the TUG of the patients with functional LLD were slower[7]. In the VAS, ratings were recorded on a 100-mm horizontal line, where 0 represented no pain and 100 the worst imaginable pain. The par-

Table 1. Baseline characteristics (mean ± SD or as otherwise indicated) of patients in the SEA, MHL and Control groups

Characteristics	SEA (n = 10)	MHL (n = 8)	Control (n = 9)	*p* Value
Age (y)	64.3 ± 5.8	63.6 ± 8.6	61.4 ± 7.2	.675
Sex (n/% women)	10/100	8/100	8/89	.354
Height (m)	1.6 ± 0.0	1.5 ± 0.1	1.5 ± 0.1	.349
Weight (kg)	56.7 ± 9.6	54.8 ± 10.9	51.3 ± 9.8	.526
Body mass index (kg/m^2)	23.5 ± 3.6	23.5 ± 4.2	22.3 ± 3.4	.740
Disease duration (median, m)	54.0	78.0	24.0	.549
KL grade (median, scale)	3.5	4.0	4.0	.922
Secondary OA (n/%)	8/80	5/63	8/89	.416
Contrateral hip conditions (n)				
Normal	2	2	4	
OA	4	4	4	.443
THA	4	2	1	
Radiographic LLD (mm)	10.5 ± 10.1	5.2 ± 3.9	10.2 ± 5.5	.296
Functional LLD (mm)	9.3 ± 5.0	8.6 ± 3.8	11.4 ± 4.9	.447
Patient-perceived LLD (n)				
No inequality	0	0	0	
Slight inequality	5	4	5	
Moderate inequality	2	4	2	.539
Large inequality	2	0	2	
Unbearable	1	0	0	
Pain score (0-100)	35.7 ± 21.7	32.9 ± 25.2	41.9 ± 29.0	.754
TUG (s)	15.0 ± 4.0	15.0 ± 6.9	24.3 ± 15.3	.109
WOMAC function score	61.6 ± 21.0	56.8 ± 18.7	52.2 ± 19.5	.569
WOMAC pain score	50.9 ± 19.2	46.3 ± 23.4	51.1 ± 9.6	.825

Abbreviations: SD, standard deviation; SEA, specific exercise approach; MHL, modifiable heel lift; KL grade, Kellgren and Lawrence grade; OA, osteoarthritis; THA, total hip arthroplasty; LLD, leg length discrepancy; TUG, Timed Up and Go test; WOMAC, Western Ontario and McMaster Universities osteoarthritis index.

ticipants were instructed to select a position on the line that corresponded to their level of pain. On the WOMAC scale, each item was measured on a 5-level Likert scale. The WOMAC pain score on the operated side was used for analysis. This scale ranged from 0 to 100, with low levels indicating severe symptoms. To test TUG, outcome assessors instructed the participants to rise from an armchair with a seat height of 43 cm, walk 3 m, turn around, return to the chair, and sit down. The test was performed twice at the usual speed of the patients, and the time from rising up out of the chair to being seated again was measured. We permitted all participants to use walking aids and patients in MHL group to use the MHL device. We used the faster result in each test.

We measured the LLDs with a radiography and a tape measure. The radiographic LLD was measured from radiography of both hips in standard anteroposterior view by using the method by Woolson *et al.*[25] as follow: the patient was in a standing position and the legs were positioned with maximum internal rotation of both hips in extension. A consistently reproducible reference point on the pelvis was obtained by drawing a line transversely through the inferior borders of 2 acetabular teardrops. The most prominent point of the lessor trochanter was taken as the corresponding reference point on the femur. A line was drawn from the femoral reference point to a perpendicular intersection with the pelvic reference line to the nearest millimeter. We used a tape measure method to measure the distance between the anterior superior and the medial malleolus, and the umbilicus and medial malleolus. The LLDs from radiography and tape measure were calculated subtracting the distance of the operated side from that of the contralateral side.

Statistical Analysis

Summary descriptive statistics were computed for the variables measured at baseline. Differences between the groups at baseline were estimated with a one-way analysis of variance (ANOVA) for parametric variables, the Kruskal-Wallis test for nonparametric variables, and the

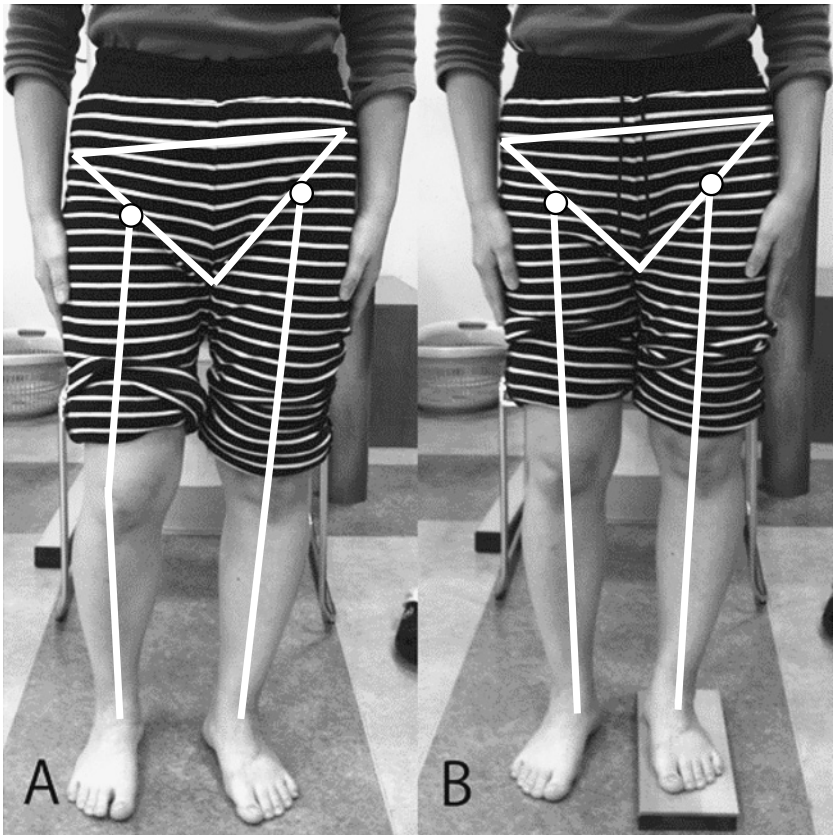

Figure 2. The standing posture of woman with the right hip arthroplasty. The lines on the pictures simulates the pelvis and legs.
(A) In static standing, the right knee was slightly flexed while the pelvis was tilted downward on the operated side. (B) In placing blocks under left foot, the right knee was extended and she felt that both legs became equal lengths.

chi-square test for nominal variables.

A split plot 2 × 3 ANOVA , with time as the within-subjects factor and group as the between-subjects factor, was used determine significant main effects of time, main effects of group, and interactions of group × time for functional LLD and secondary outcome variables. Multiple comparison analysis using the Dunnett's test was performed. The degrees of patient-perceived LLD in the 3 groups were analyzed using the chi-square test. A P value of <0.05 was considered to be significant. The Bonferroni-corrected chi-square test revealed a significant difference between each of SEA and control group, and MHL and control groups. A P value of <0.025 was considered statistically significant.

In order to confirm the validity of functional LLD assessed with the block test, Pearson's correlation coefficients were calculated between the block test data and the LLDs from a radiography and a tape measure.

We calculated post hoc power and effect sizes to detect the statistical power of all outcomes, using G*Power 3.1.0 software. The data were analyzed on the basis of the intention-to-treat principle using SPSS version 11.0 for Windows (SPSS Inc, Chicago).

Results

Of 72 patients, 39 did not have functional LLD and patient-perceived LLD. The 33 participants with functional leg lengthening of the operated side were allocated 1 week after the surgery as follows: 11 into the SEA group, 12 into the MHL group, and 10 into the control group (Fig. 3). During interventions, 3 patients in the MHL group were lost before follow-up (1 patient declined to participate and 2 patients refused due to a problematic recovery). In the analysis phase, 1 patient from each group was excluded due to a large number of missing values. The mean of MHL height ± SD was 8.1 ± 3.7 mm (range, 5-15 mm) at baseline and 3.8 ± 3.5 mm (range, 0-10 mm) at t1. In the MHL group, 3 patients released the use of MHL because their functional and patient-perceived LLD were eliminated before hospital discharge.

The characteristics of the patients are summarized in Table 1. At baseline, there were no statistically significant differences (p>0.05) between all 3 groups.

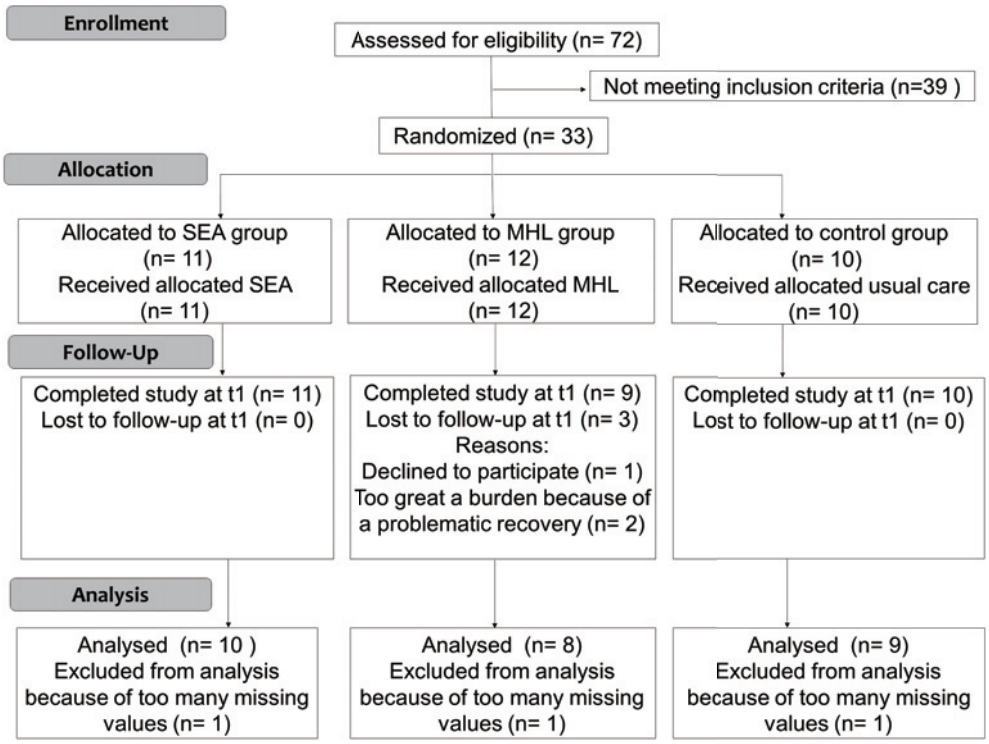

Figure 3. Flow diagram of enrollment, randomization, and loss to follow-up.
Abbreviations: SEA, specific exercise approach; MHL, modifiable heel lift.

For results of the split plot ANOVA on the functional LLD and all secondary outcomes, the time was statistically significant and the group and time-group were not statistically significant (Table 2). For results of the multiple comparison analysis on the functional LLD and secondary outcomes, the functional LLD at t1 was significantly smaller for the SEA and MHL groups than for the control group ($p<0.05$; Table 2). Fig. 4 shows the degrees of patient-perceived LLD at t1. A significant difference in the extent of patient perceived LLD was found between the 3 groups (p=0.01, Effect size (Cohen's w) =.56, Power =.55). The Bonferroni-corrected chi-square test revealed that there was statistically significant difference between SEA and control groups (p=0.005). The rates of "no inequality" and "slight inequality" in the SEA group were higher than those in the control group. The rate of "moderate inequality" in the control group was higher than that in SEA group. While the Bonferroni-corrected chi-square test revealed that there was no statistically significant difference between MHL and control groups (p=0.055). The results of secondary outcomes at t1 including the results of post hoc power analysis are showed in Table 2; There were no significant differences between the 3 groups.

Pearson's correlation coefficients between the block test data and the LLDs from a radiography and a tape measure are shown in Table 3. The only significant correlation was between the block test and the LLD calculated from the distance between the umbilicus and the medial malleolus (p <.05).

Discussion

To our knowledge, this study is the first to assess the effect on functional LLD of patients after THA of the SEA and MHL interventions added to standard inpatient rehabilitation care. The main result was that Patients in both intervention groups improved in functional LLD and patients in SEA group improved in perceived LLD more than control group. The SEA induced a significant improvement in functional and patient-perceived LLDs and The MHL induced a significant improvement in functional LLD in the short term after THA.

Changes in Functional LLD

On baseline (t0), there were no statistically differences in the height of functional LLD between 3groups. During their 2-week, the intervention groups performed SEA or MHL in addition to the standard rehabilitation program. After the interventions, although the main effect of group and time-group was not significant, the effect size for changes in functional LLD was 0.43, described as "large" by Cohen[26]. The power value for changes in functional LLD was 0.67, described as "acceptable" for physical measures[27]. There were statistically significant differences in the height of LLD between the SEA and control groups and the MHL and control groups on the multiple comparison analysis. In case that the ANOVA p-value can indicate that there are no differences between the means while the multiple comparisons output indicates that some means that are different, the

Table 2. Comparison of functional LLD and secondary outcomes at baseline (t0) and 3 weeks after the surgery (t1) among the groups

Measurements	t0 (n = 27)	t1 (n = 27)	Main effect (*P*) Time	Group	Interaction (*P*)	Effect size (Cohen's f)	Power
Functional LLD (mm)							
SEA	9.3 ± 5.0	3.3 ± 3.1					
MHL	8.6 ± 3.8	2.2 ± 2.1					
Control	11.4 ± 4.9	6.4 ± 4.0	<.001	.133	.725	.43	.67
Pain (0-100)							
SEA	35.7 ± 21.7	6.7 ± 8.0					
MHL	32.9 ± 25.2	16.3 ± 25.0					
Control	41.9 ± 29.0	16.4 ± 18.8	.003	.352	.512	.31	.38
TUG (s)							
SEA	15.0 ± 4.0	9.1 ± 1.9					
MHL	15.0 ± 6.9	11.4 ± 4.3					
Control	24.3 ± 15.3	12.5 ± 5.7	.013	.066	.475	.56	.88
WOMAC function score							
SEA	61.6 ± 21.0	80.5 ± 15.6					
MHL	56.8 ± 18.7	84.9 ± 8.3					
Control	52.2 ± 19.5	78.8 ± 13.5	<.001	.357	.446	.31	.38
WOMAC pain score							
SEA	50.9 ± 19.2	89.5 ± 11.2					
MHL	46.3 ± 23.4	83.8 ± 16.2					
Control	51.1 ± 9.6	78.3 ± 18.5	<.001	.318	.346	.32	.42

Note. Data are mean ± SD.

*: Compared with the control group, relatively smaller in functional LLD occurred for the SEA group ($P = .039$) and for the MHL group ($P = .011$).

Abbreviations: LLD, leg length discrepancy; SEA, specific exercise approach; MHL, modifiable heel lift; TUG, Timed Up and Go test; WOMAC, Western Ontario and McMaster Universities osteoarthritis index.

multiple comparisons output can be trusted because the Dunnett test was incorporated to protect a level of statistical significance without the ANOVA[28]. Given this theory, there were statistically significant differences in functional LLD for SEA and MHL groups compared with control group.

The effects of SEA found here is similar to the those found in a previous study which examined the effects of muscle energy techniques included post-isometric relaxation on patient-perceived LLD[10]. Post-isometric relaxation to increase a restricted range of motion is well known in the proprioceptive neuromuscular facilitation techniques[15,29,30]. The side shift and hitch exercises are known to be useful for idiopathic scoliosis[16]. Previous studied have reported that abduction contracture of hip[9] and rigid lumber spine[31] can cause functional LLD. Decreased functional LLD in the SEA group can result from recovery of mobility of the hip joint and the lumber spine. Therefore, we suggest that early postoperative SEA program is necessary for patient with functional LLD after THA. Future studies are recommended to determine the influence of these techniques on the range of motion.

The effect of MHL should be discussed carefully, as there is disagreement in the literature about the use of a heel lift or shoe lift for the treatment of functional LLD[13,32]. Brander *et al.*[13] proposed that shoe lift should not be used for 6 months after surgery until most of the soft-tissue contributors have healed. However, 32%[20] or 30%[1] of patients reported the presence of patient-perceived LLD in the long term after THA and had a poor functional outcome. It may be difficult to predict a residual functional and patient-perceived LLD in the long term and to clinically prescribe

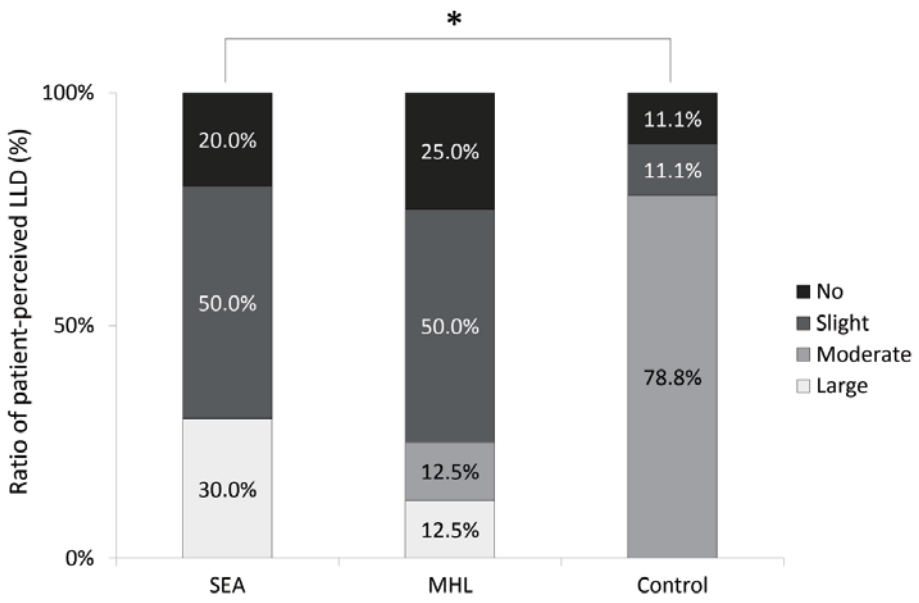

Figure 4. Bar chart showing the percentage of each degree of patient-perceived LLD at t1 for the 3 groups.
*: There was a statistically significant difference with Bonferroni-corrected chi-square test between SEA and control groups ($p < 0.01$). SEA group had a higher percentage of "no" and "slight" of patient-perceived LLD than control group.
Abbreviations: LLD, leg length discrepancy; SEA, specific exercise approach; MHL, modifiable heel lift.

Table 3. Pearson's correlation coefficients between the block test and the others LLDs by a radiography and a tape measure at 3 weeks after the surgery (t1)

	Tape measure		
	ASIS and MM	Umbilicus and MM	Radiographic LLD
Block test	.201	.439*	.167

*: P <.05.
Abbreviations: LLD, leg length discrepancy; ASIS, anterior superior iliac spine; MM, medial malleolus

the heel lift and shoe lift after discharge. Therefore, we used the heel lift device which was able to modify the height based on the measurement of functional LLD. We have understood that the use of heel lifts with "non-modifiable" heights in early stage could inhibit the improvement of functional LLD, nevertheless the use of heel lifts with "modifiable" heights could help to improve functional LLD. It is usually observed that the hip and the knee joint of the operated side in patients with functional LLD are slightly flexed, whereas the pelvis is tilted downward on the affected side as a result of the contracture of the lateral and or anterior structure[33]. This flexed hip joint position can discourage ameliorating the contracture of the tensor fasciae latae which causes the pelvic obliquity because the tensor fasciae latae was shortened by hip flection and abduction position. Therefore, continuing the extended hip joint position with the heel lift could assist the shortening muscles to stretch. Our results give preliminary support to the early postoperative implementation of the heel lift to promote the recovery of functional LLD.

Considering the results of correlations between the block test data and the LLDs from a radiography and a tape

measure and previous studies, the functional LLD in this study has a certain validity. First, the functional LLD assessed with the block test was correlated significantly with the LLD calculated from the distance between the umbilicus and the medial malleolus alone. The LLDs calculated from the distance between the umbilicus and the medial malleolus is used as the functional leg length[34,35], on the other hand, the hip radiographic LLD and the LLD calculated from the distance between the anterior superior iliac spine and medial malleolus are used as the structural LLD[6,36]. Second, from previous studies which used the same block test method as the present study, it has been reported that the LLD measured by the block test was related with lateral flexibility of the lumber spine[31], the operative hip adduction angle and lateral pelvic tilt angle[37]. Koga et al. reported that the LLD measured by the block test was not associated with the radiographic LLD[31]. Therefore, we suggest that the LLD measured by the block test strongly indicates the functional LLD resulting from pelvic obliquity due to hip contracture and lumber scoliosis compared to structural LLD.

Changes in Patient-perceived LLD

On baseline (t0), there were no statistically differences in the degree of patient-perceived LLD between 3 groups. After the 2-week interventions, there was statistically significant differences in the degree of patient-perceived LLD between 3 groups. The effect size for changes in the degree of patient-perceived LLD was 0.56, described as "large"[26]. The power value for changes in the degree of patient-perceived LLD was 0.55, described as "acceptable" for cognitive values[27]. Additionally, there was statistically significant difference in the degree of patient-perceived LLD between SEA and control groups by Bonferroni-corrected chi-square test. While there was no significant difference in the degree of patient-perceived LLD between MHL and control groups by Bonferroni-corrected chi-square test. Nakanowatari *et al.*[7] and Harris *et al.*[38] reported that patient-perceived LLD was associated with functional LLD. Therefore, changes in the degree of patient-perceived LLD can result from changes in functional LLD by the SEA. However, there were no significant difference in the patient-perceived LLD between MHL and control groups in spite of the improvement of functional LLD as well as SEA group. Considering the different results of patient-perceived LLD between SEA and MHL groups, it might have been caused by smaller sample size of MHL group and more specific effectiveness of SEA intervention to improve patient-perceived LLD. Therefore, future study should focus on specific treatment effectiveness of each intervention.

Secondary Outcome Measures

There were no significant differences between the 3 groups in the secondary outcomes at t1. The effect size for changes in secondary outcome measures were from 0.13 to 0.37, described as "small to medium" by Cohen[26]. The power values for changes in these measures were from 0.13 to 0.35, described as "underpowered". It has been found that the greatest improvement of the scores for physical health, such as those for pain and physical function seemed to take place within the first three to six months after surgery[39]. Furthermore, previous studies have reported that absence or presence of functional and patient-perceived LLDs was associated with TUG at 2 months[7] and physical function at 3 months after surgery[2]. The evaluation period of this study might be too early stage after the surgery. Future study should include a follow-up on longer period after surgery. Additionally, the results of TUG of MHL group were not significantly faster than other groups in spite of using the MHL devise. Further study should make consideration for the habituation term to adjust the MHL device for patients.

Study Limitations

A limitation of our study was its small sample size. This limitation could make the statistically difference between the split plot ANOVA output and multiple comparison output and reduce the statistical power of our analyses. However, the results of functional LLD and the degrees of patient-perceived LLD have indicated the power values to be able to deem acceptable for initially designed study[27]. Secondly, we used mainly subjective measurements. Because patients were not blinded to treatment allocation, the effectiveness of SEA and MHL may contain a placebo effect. However, in an intervention of rehabilitation trial similar to this study, it is difficult to blind patients to the treatment. Thirdly, the measurement conditions of the block test method with patient perception may not be confirmed by previous studies. Additionally, periods of follow-up in this study may be inadequate. Therefore, subsequent research is in progress to investigate the effectiveness of SEA and MHL in the long term and should confirm the measurement conditions of the block test.

Conclusion

Early postoperative SEA was clinically effective in improving functional LLD and patient-perceived LLD and MHL was effective in improving functional LLD compared with a standard rehabilitation program in the short term in patients with these LLDs after THA.

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