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Dramatic Effects of New Home Exercises for Patients with Osteoarthritis of the Hip: Pericapsular Soft Tissue and Realignment Exercises

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Abstract

Objective: Many patients with hip Osteoarthritis (OA), even those with Harris Hip Scores (HHS) below 60 points, have motion pain resulting from joint contracture. In these patients, pain occurs on standing and at first steps but decreases during walking. Motion pain seems to improve with exercise therapy, whereas pain during walking caused by subchondral bone exposure on the joint surface may need surgery. The goal of this study was to investigate the effectiveness of Pericapsular Soft Tissue and Realignment (PSTR) exercises for patients with OA of the hip, including those with HHS below 60 points.

Methods: This retrospective observational study included 1,077 outpatients with mild to severe symptomatic and radiographic OA of the hip who were treated with patient education and supervised PSTR exercises. Approval of the local committee was obtained. Of the 1,077 patients who performed PSTR exercises, 792 were excluded from analysis. The remaining 285 participants were divided into two groups: the Unilateral OA group (no pain [HHS pain score, 44 points] in the opposite hip) and the Bilateral OA group (HHS pain score below 40 points bilaterally). HHS, pain according to numerical rating scale, range of motion, opening angle of the hip according to modified Patrick's test, maximum strength of the hip abductors, and SF-36 were evaluated.

Results: Among the 285 patients, 154 had unilateral OA and 131 had bilateral OA. Both groups showed significant HHS improvement at 3 month and 1 year follow-ups, regardless of HHS at baseline. Significant improvements in pain on the numerical rating scale, opening angle of the hip, and maximum muscle strength were noted at 3 month follow-up (P<0.0001-P<0.001). Among patients with HHS below 60 points at baseline, 38 had unilateral OA and 49 had bilateral OA. This study's main limitation was that it was retrospective and uncontrolled.

Conclusions: Our results suggest that PSTR exercises may improve hip function, even in patients with an HHS below 60 points.

Keywords: Hip osteoarthritis; Home exercise; PSTR exercise; Postpone or prevent surgery; Harris Hip Score (HHS)

Introduction

Most studies that have examined exercise as non-surgical treatment for Oteoarthritis (OA) of the hip have involved strength training, stretching, functional training, and aerobic fitness programs [1-5]. The reported inclusion criteria for exercise therapy include a Harris Hip Score (HHS) [6] between 60 and 95 points, whereas Fernandes et al. and Svege et al. [7,8] recommend Total Hip Arthroplasty (THA) for patients with an HHS below 60 points. Numerous studies have included participants with mild to moderate OA of the hip [1,7-12]. However, patients with an HHS below 60 points may wish to postpone surgery more than patients with an HHS above 60 points. Most patients with an HHS above 60 points do not have much disturbance of Activities of Daily Living (ADL). The main reasons for avoiding or postponing surgery are work, child-rearing, or caring for one's parents. Long-term treatments to postpone or prevent surgery are needed that allow patients to exercise at home while continuing to work. Manual therapies that require hospital visits are not suitable as long-term treatment to postpone or prevent surgery.

Several studies have reported that neuromuscular exercise was effective at treating severe OA of the hip [13-15]. In those studies, exercise was performed preoperatively to improve postoperative outcomes of THA, not to postpone or prevent hip surgery. In a randomized clinical trial, Bennell et al. [16] implemented a multimodal physical program for patients with OA of the hip. The program consisted of manual therapy techniques (hip thrust manipulation and hip–lumbar spine mobilization), strengthening of the hip abductors and quadriceps, stretching, Range-of-Motion (ROM) exercises, functional balance and gait drills, and provision of a walking stick if appropriate. Bennell et al. [16] found that the physical therapy program conferred no additional clinical benefit over a realistic sham for 51% of patients with moderate to severe OA of the hip; they also found that the program was associated with relatively frequent but mild adverse effects [17]. No reported programs appear to have improved hip function in patients with an HHS below 60 points sufficiently to allow postpone or prevention of surgery.

Worsening OA of the hip results in anterior pelvic tilt, elevation

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of the greater trochanter, and adduction contracture of the affected hip [18-21]. When the pelvis is tilted anteriorly, muscles may follow paths that differ from their anatomical paths. The load distribution may also differ from physiological load distribution. Anterior pelvic tilt and elevation of the greater trochanter cause apparent shortening of leg length on the affected side. This apparent leg-length difference [20] may result in instability while walking. Failure to correct pelvic malalignment before initiating strengthening exercises may cause imbalance between the affected and nonaffected legs and exacerbate OA of the hip. Therefore, we developed an exercise to realign the pelvis.

In our past experience, we have found that many patients with OA of the hip complained of hip pain on standing and at first steps when starting to walk, with decreased hip pain during walking. Many patients have motion pain with absent or mild walking pain. Even patients with an HHS below 60 points have this motion pain. We hypothesized that motion pain could be caused by contracture of the hip joint, whereas walking pain could be caused by contact with the subchondral bone resulting from loss of cartilage from the joint surface. Motion pain seems to improve with exercise therapy, whereas walking pain may require surgery. Walking instability caused by anterior pelvic tilt and elevation of the greater trochanter causes repetitive Pericapsular Soft Tissue (PST) injury to the joint capsule, ligaments, and inner muscles, resulting in contracture of the affected hip. Therefore, correction of pelvic malalignment before initiating strengthening exercise is necessary to decrease motion pain, in addition to correction of apparent leg-length differences. We hypothesized that decontracure exercise for PST and realignment of the pelvis (PSTR exercise) may improve hip function for patients with OA of the hip and an HHS below 60 points. Decontracture may provide a useful method to ease joint stiffness.

The current study investigated the effect of PSTR exercises on function in patients with OA of the hip; we also compared the results of these exercises in patients with unilateral versus bilateral OA of the hip. It is recognized that the results of unilateral OA of the hip is better than that of bilateral OA of the hip for one treatment (exercise, surgery etc.). So the result for one exercise is analyzed in unilateral versus bilateral OA of the hip separately in general.

Methods

Participants

Inclusion criteria were as follows

1. Patients who wish to prevent surgery
2. Patients with 18-85 years at consent
3. Patients with hip pain for more than 3 months
4. Patients eligible for more than 2 of the following 1-3 criteria (ACR: American College of Rheumatology criteria [22]) or 4:-

4.1. ESR<20 mm/h)

4.2. Osteophytes (femoral or acetabular)

4.3. joint space narrowing

4.4. hip pain due to acetabular dysplasia

5. Patients in which the difference in the height of the tip of the greater trochanter was 2.0 cm or less on standing full-length radiographs of the lower extremities

Exclusion criteria were as follows

1. Patients who undergo the treatment of cardiovascular diseases
2. Patients who undergo the treatment of cancer
3. Patients who have severe osteoporosis/dysfunction in the lower extremities due to an accident or disease besides OA of the hip (e.g. osteoarthritis with the knee above K/L grade 2)
4. Patients with pregnancy
5. All kinds of surgeries of the lower extremities
6. Patients who undergo the instruction of PSTR exercises by therapists within one year (patients who performed exercises by themselves according to the instruction of the book are not excluded)
7. Patients with dementia who seem to be not eligible for exercises (Doctor's judgment e.g. patients who have difficulty with writing the diary or understanding exercises)
8. Patients with osteonecrosis of the femoral head
9. Patients with a Subchondral Insufficiency Fracture (SIF) of the femoral head
10. Patients with Perthes disease
11. Patients with rheumatoid arthritis
12. Patients with other rheumatic disease with spondyloarthritis
13. Patients with infection
14. Patients in which malignant diseases are suspected at the hip joints or around the hip
15. Patients taking analgesics (even if only once)
16. Patients receiving chiropractic treatment or other hip therapy
17. Other patients in which doctor considered that they were not eligible (e.g. Dislocation of the femoral head into the buttocks)

MRI scans routinely performed during initial examination were evaluated to rule out patients who met these exclusion criteria. In patients with SIF of the femoral head, weight was kept off the affected side and medication was administered to treat osteoporosis. If pain resulting from OA of the hip remained after the SIF healed, patients performed PSTR exercises but were excluded from this study.

The study was carried out in accordance with the Helsinki Declaration and was approved by the Fukuoka Wajiro Hospital Medical Research Ethics Committee. Authors obtained informed consent from participants when required for protection of human subjects.

The patients were observed by one hospital and any special recruitment such as advertisement in a local newspaper was not performed for this study. The inclusion was performed at Arthris Center of Fukuoka Wajiro Hospital in Fukuoka, Japan. One orthopedic surgeon examined all radiographs and three physical therapists of PSTR exercise specialist rated the patient's symptoms (HHS).

Interventions

Patient education

Precautions during everyday activities

Patients were instructed to avoid strain or impact on the hip joint and overloading. In principle, lifting less than 5 kg was permitted; lifting up to 10 kg was permitted for up to 15 min, if absolutely necessary. Based on this principle, patients were also instructed regarding sports, recreation, and other social activities.

Precautions during exercise

Patients were instructed to stop exercising if they experienced increased pain. Patients then attempted to exercise fewer times per day. If the pain recurred, patients were instructed to stop the program.

PSTR home exercises: Exercises 1-5 were basic exercises performed by all patients.

1. **Pelvic realignment exercise:** This exercise was performed every morning after waking and before walking. This exercise was performed before a Closed Kinetic Chain (CKC) exercise involving the hip abductors. Exercises ①–④ below adjusts the anterior pelvic tilt and elevation of the greater trochanter on the affected side. Exercises were to be performed in the order indicated. The detail of anterior pelvic tilt, elevation of the greater trochanter and each exercise were shown in Supplementary Information.

① **Exercise for the lower back:** This exercise increases flexibility of the erector spinae and the rectus abdominis.

② **Exercise to correct apparent leg-length differences:** Many patients with OA of the hip have apparent leg-length differences resulting from the posture they have adopted for a prolonged period because of pain. Apparent leg-length differences cause pain in the lower back and in other joints, such as the knee. This exercise increases flexibility of the erector spinae, the transversus abdominis, and internal oblique muscles.

③ **Adjustment of the greater trochanter:** This exercise strengthens the gluteus maximus and adjusts the level of the greater trochanter.

④ **Adjustment of the Anterior Superior Iliac Spine (ASIS):** This exercise increases flexibility of the sartorius, hip abductors, and rectus abdominis.

2. **Back-and-forth exercise:** This exercise is performed before the CKC exercise involving the hip abductors to obtain ROM that more closely approximates the physiological ROM.

3. **CKC exercise involving the hip abductors of the tensor fasciae latae**

4. **Correction of bowed legs**

5. **Stretching of the quadratus femoris:** This exercise increases the flexibility of the Quadratus femoris and adjusts the anterior pelvic tilt on the affected side. Exercises 3, 4, and 5 can be done at any time of day after the pelvic realignment exercise. However, the back-and-forth exercise is done before the CKC exercise involving the hip abductors.

Patients were instructed by a physical therapist and were supervised while exercising once every 2 weeks during the first 12 weeks. After 12 weeks, patients were instructed to perform the exercises at home as part of their daily routine.

Outcome measures: 792 patients out of 1,077ones who performed PSTR exercise were excluded and 285 participants were analyzed. Patients were divided into two groups: the Unilateral OA group (no pain [HHS pain score of 44 points] in opposite hip) and the Bilateral OA group (pain in both hips, HHS pain score below 40 points bilaterally). In the Bilateral OA group, the more painful hip joint was analyzed.

Figure 1: Modified Patrick's test.

Measures of characteristics at baseline: age, sex, body mass index, duration of pain, work status, and Kellgren-Lawrence (KL) arthritis grade [23].

Measures of symptoms at baseline, 3-month, and 1-year follow-up

Month follow-up: HHS, HHS pain score, pain on a Numerical Rating Scale (NRS) [24], ROM, opening angle of the hip (opening angle of the hip according to a modified Patrick's test, (Figure 1) [25], maximum strength of hip abductors (a hand-held dynamometer was used to evaluate muscle strength), and SF-36 scores [26-28].

Year follow-up

HHS, HHS pain score, and SF-36 scores

No change in the KL grade from baseline to 1 year follow-up was noted. None of the participants received analgesics, including nonsteroidal anti-inflammatories, paracetamol, opioid analgesics, or glucosamine/chondroitin products.

Statistical analyses

Only treatment teams entered and collected data from electronic medical charts. Data scrubbing and statistical analyses were performed by the Clinical Research Support Center Kyushu.[1] A paired t-test was used for intra-personal change in endpoints between baseline and 3-months later or between baseline and 1 year later. Mean difference and its 95% confidence interval of endpoints were estimated by using t-distribution. All analyses were performed with Stata version 13 (Stata Corp., College Station, Texas). A value of $p<0.05$ was statistically significant.

Results

Characteristics of the patients

PSTR exercises were performed by 1,077 patients with OA of the hip who visited the Arthritis Center at Fukuoka Wajiro Hospital from April 2011 to January 2014. Of these, 792 patients were excluded due to

[1]The differences in the background parameters between unilateral and bilateral groups were tested by t-test for continuous variables and Chi-square test for discrete variables.

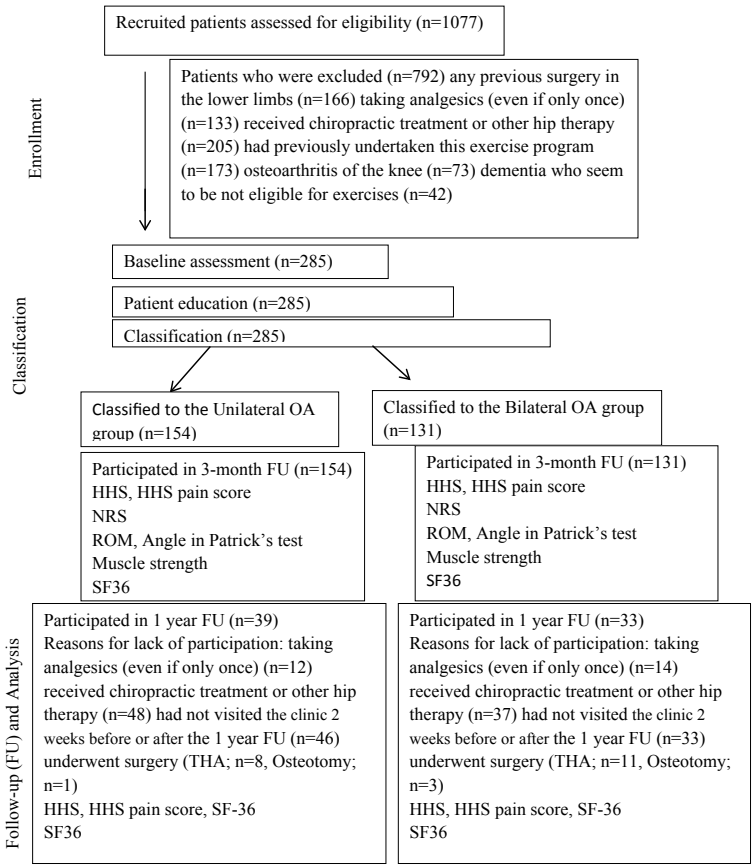

Figure 2: Steps for patients participating in this study.

Variables§	Unilateral Group (n=154)	Bilateral Group (n=131)	P*
Age (years)	56.4 (14.2)	54.2 (12.8)	0.16
Women, no (%)	133 (86.4%)	123 (93.9%)	0.036
BMI (kg/m^2)	22.0 (3.3)	22.1 (3.2)	0.8
HHS (0-100)	74.29 (17.76)	65.52 (17.32)	<0.0001
No. (%) below 59	n=38 (25.0%)	n=49 (37.4 %)	0.024
No. (%) above 60	n=114 (75.0%)	n=82 (62.6%)	-
Duration of pain (months)	30.8 (50.4)	55.7 (98.7)	0.007
K/L grade			
Grade 1	57	51	0.97
Grade 2	32	29	-
Grade 3	39	32	-
Grade 4	20	16	-
Minimal Joint Space (MJS, mm)			
Lateral/concentric OA type	2.10 (1.76); n=127	3.04 (1.83); n=121	0.016
Medial OA type	n=27	n=10	-
Work status, No. (%)	-	-	0.98
1) Currently employed	n=75 (49.7%)	n=63 (48.5%)	-
2) Unable to work due to health reasons	n=2 (1.3%)	n=2 (1.5%)	-
3) Retired, not due to health reasons	n=2 (1.3%)	n=1 (0.8%)	-
4) Unemployed	n=22 (14.6%)	n=18 (18.9%)	-
5) Homemaker	n=50 (33.1%)	n=46 (35.4%)	-
§ Mean (Standard Deviation) or frequency (percent)			
No change in the K/L grade at the baseline and at the 1 year follow-up was noted			
†t-test for continuous variables and Chi-square test for discrete variables. P<0.05 was significant.			

Table 1: Baseline characteristics.

exclusion criteria and 285 fulfilled the inclusion criteria were divided into Unilateral Group (n=154) and Bilateral Group (N=131) (Figure 2). Baseline characteristics of the patients were presented in Table 1. Exclusion criteria from beseline to 1 year follow-up were as follows. Patients fulfilled the following criteria were excluded as far as we confirmed in the electronic medical charts.

1. Patients taking analgesics (even if only once)
2. Patients receiving chiropractic treatment or other hip therapy
3. Patients who did not visit the clinic within 2 weeks before or after the 3 months or 1-year follow-up
4. Patients who underwent surgery

In Unilateral Group 38 patients had HHS below 59 points (25.0%) and 114 patients had HHS above 60 points (75.0%). Two patients were eliminated because some of the data on their HHS scores were missing. In Bilateral Group 49 patients had HHS below 59 points (37.4%) and 82 patients had HHS above 60 points (62.6%) (Table 1). 115 patients were excluded prior to 1-year follow-up in Unilateral Group (taking analgesics: n=12, received chiropractic treatment or other hip therapy: n=48, had not visited the clinic 2 weeks before or after 1-year follow-up: n=46, underwent surgery: THA; n=8, Ostoetomy; n=1). 98 patients were excluded prior to 1-year follow-up in Bilateral Group (taking analgesics; n=14, received chiropractic treatment or other hip therapy: n=37, had not visited the clinic 2 weeks before or after 1-year follow-up: n=33, underwent surgery: THA; n=11, Ostoetomy; n=3).

Changes in outcome measures except SF-36

Changes from baseline to 3-month follow-up: The results of all included patients are shown in Tables 2a and 2b. Significant

Tests	Category	Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 Y)	1 year	Mean (95% confidence interval)		P value
HHS	Unilateral	74.29 (17.76)	81.20 (14.95) (N=152)	6.91	(4.30 to 9.52)	<0.0001	75.21(16.91)	87.08 (15.73) (N=38)	11.87	(4.40 to 19.34)	0.003
	Bilateral	65.52 (17.32)	76.80 (18.65) (N=131)	11.28	(8.34 to 14.22)	<0.0001	65.42(16.07)	82.06 (16.39) (N=33)	16.64	(9.73 to 23.55)	<0.0001
HHS pain score	Unilateral	26.10 (14.43)	31.70 (11.41) (N=154)	5.6	(3.31 to 7.88)	<0.0001	27.44(14.28)	36.26 (10.92) (N=39)	8.82	(2.93 to 14.71)	0.004
	Bilateral	19.62 (13.03)	28.79 (13.29) (N=131)	9.18	(6.65 to 11.70)	<0.0001	18.79(12.19)	31.70 (12.86) (N=33)	12.91	(7.29 to 18.52)	<0.0001
NRS	Unilateral	4.32 (2.22)	3.21 (2.22) (N=150)	-1.11	(-1.45 to -0.77)	<0.0001	-	-	-	-	-
	Bilateral	4.88 (1.98)	3.61 (2.17) (N=130)	-1.27	(-1.66 to -0.88)	<0.0001	-	-	-	-	-
Angle in a modified Patrick's test	Unilateral	51.44 (17.51)	57.30 (17.82) (N=111)	5.86	(3.09 to 8.63)	<0.0001	-	-	-	-	-
	Bilateral	51.67 (17.80)	57.75 (15.26) (N=102)	6.08	(3.62 to 8.54)	<0.0001	-	-	-	-	-
Muscle strength (Nm)	Unilateral	41.70 (18.05)	48.16 (20.46) (N=132)	6.46	(3.19 to 9.73)	<0.001	-	-	-	-	-
	Bilateral	40.56 (16.82)	47.36 (19.87) (N=118)	6.8	(4.10 to 9.49)	<0.0001	-	-	-	-	-
Unilateral: Group with unilateral OA of the hip (no pain in the opposite hip)											
Bilateral: Group with bilateral OA of the hip (pain in the opposite hip)											
Angle in a modified e Patrick's test: The opening angle of the hip in a modified Patrick's test											
A Hand Held Dynamometer was used to evaluate muscle strength											
Parenthesis were SD											
Two-sided p<0.05 was significant											

Table 2a: Difference in the HHS, HHS pain score, pain on an NRS, the opening angle of the hip according to Patrick's test, and muscle strength at the baseline and follow-up at 3 months and 1 year.

Types of Movement	Category	Baseline	3 months	Mean (95% confidence interval)		P value
flexion	Unilateral OA	109.38 (18.61)	110.49 (18.16) (N=152)	1.12	(-0.44 to 2.68)	0.16
	Bilatetal OA	107.50 (18.60)	110.65 (19.65) (N=130)	3.15	(1.41 to 4.90)	<0.001
extension	Unilateral OA	10.93 (7.45)	11.69 (6.85) (N=151)	0.76	(-0.21 to 1.73)	0.12
	Bilatetal OA	10.46 (7.25)	11.38 (7.29) (N=130)	0.92	(-0.31 to 2.16)	0.14
abduction	Unilateral OA	26.99 (10.38)	28.64 (9.78) (N=151)	1.66	(0.41 to 2.90)	0.009
	Bilatetal OA	25.08 (10.44)	27.77 (11.22) (N=130)	2.69	(1.06 to 4.32)	0.001
adduction	Unilateral OA	10.20 (4.95)	11.15 (4.97) (N=152)	0.95	(0.05 to 1.86)	0.04
	Bilatetal OA	9.92 (4.90)	10.73 (4.41) (N=130)	0.81	(-0.15 to 1.76)	0.1
external rotation	Unilateral OA	34.41 (11.83)	36.45 (12.65) (N=152)	2.04	(0.60 to 3.48)	0.006
	Bilatetal OA	35.86 (12.15)	37.30 (12.29) (N=128)	1.45	(-0.13 to 3.02)	0.07
internal rotation	Unilateral OA	28.78 (16.21)	30.46 (17.02) (N=152)	1.68	(0.05 to 3.31)	0.04
	Bilatetal OA	28.57 (16.16)	32.09 (16.16) (N=129)	3.53	(1.94 to 5.11)	<0.0001
Parenthesis were SD						
Two-sided p<0.05 was significant						

Table 2b: Difference in ROM at baseline and follow-up at 3 months.

differences in HHS were noted in patients in both the Unilateral and Bilateral OA groups (p<0.0001). Significant differences in HHS were noted between baseline and 3 month follow-up for patients with a KL grade of 1-3 but not for patients with a KL grade of 4 (Table 2c). Significant differences in HHS were noted between the two time points in patients in the Bilateral OA group who had a hip opening angle smaller than 30° according to Patrick's test, but not in the Unilateral OA group. Significant differences in HHS were noted between the two time points for patients in both the Unilateral and Bilateral OA groups who had an opening angle of the hip greater than 30° (Table 2d). Significant differences in HHS were noted in patients in both the Unilateral and Bilateral OA groups who had an HHS below 60 points at baseline (p<0.0001) (Table 2e). Table 2e shows the results of patients with an HHS above 60 points.

Changes from baseline to 1-year follow-up: Table 2a shows the results of HHS and HHS pain scores. Significant differences in HHS were noted in patients in both the Unilateral (p=0.003) and Bilateral OA groups (p<0.0001). Significant improvements in HHS were noted in both the Unilateral (p<0.0001) and Bilateral OA groups (p<0.001) among patients with an HHS below 60 points at baseline (Table 2e). Table 2e shows the results of patients with a baseline HHS above 60 points.

Grades	Category	Baseline	3 months	Mean (95% confidence interval)		P value
K/L grade 1	Unilateral OA	81.58 (17.47)	87.93 (11.08) (N=57)	6.35	(2.20 to 10.50)	0.003
	Bilateral OA	71.73 (15.37)	84.22 (14.34) (N=51)	12.49	(8.39 to 16.59)	<0.0001
K/L grade 2	Unilateral OA	75.28 (17.19)	84.97 (12.2) (N=32)	9.69	(3.31 to 16.06)	0.004
	Bilateral OA	64.59 (17.54)	80.52 (15.37) (N=29)	15.93	(9.00 to 22.86)	<0.0001
K/L grade 3	Unilateral OA	67.64 (15.31)	74.05 (14.45) (N=39)	6.41	(0.68 to 12.14)	0.03
	Bilateral OA	60.13 (17.21)	69.50 (17.90) (N=32)	9.38	(3.88 to 14.87)	0.002
K/L grade 4	Unilateral OA	66.60 (16.50)	69.15 (17.47) (N=20)	2.55	(-2.00 to 7.10)	0.26
	Bilateral OA	55.25 (17.11)	58.25 (21.62) (N=16)	3	(-8.96 to 14.96)	0.6
No change in the KL grade at the baseline and at the 3 months follow-up was noted						
Parenthesis were SD						
Two-sided P<0.05 was significant						

Table 2c: HHS in accordance with the K/L grade.

Tests	Category	Baseline	3 months	Mean (95% confidence interval)		P value
Angle<30° in a modified Patrick's test	Unilateral OA	76.67 (18.97)	82.67 (12.72) (N=15)	6	(-3.12 to 15.12)	0.18
	Bilateral OA	67.13 (17.32)	74.40 (20.74) (N=15)	7.27	(2.25 to 12.28)	0.008
Angle 30°-50° in a modified Patrick's test	Unilateral OA	67.19 (18.13)	73.11 (17.52) (N=37)	5.92	(0.26 to 11.58)	0.04
	Bilateral OA	56.81 (18.85)	70.06 (18.36) (N=31)	13.26	(4.78 to 21.74)	0.003
Angle>50° in a modified Patrick's test	Unilateral OA	76.17 (17.29)	84.55 (13.77) (N=58)	8.38	(4.18 to 12.57)	<0.001
	Bilateral OA	70.85 (14.43)	81.95 (14.55) (N=55)	11.09	(7.23 to 14.95)	<0.0001
Angle in a modified Patrick's test: The opening angle of the hip in a modified Patrick's test						
Parenthesis were SD						
Two sided P<0.05 was significant						

Table 2d: HHS in accordance with the opening angle of the hip in a modified Patrick's test.

HHS at different Points	Category	Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 Y)	1 year	Mean (95% confidence interval)		P value
HHS<60 points at baseline	Unilateral	48.38 (7.35)	70.81 (18.04) (N=38)	22.43	(16.07 to 28.79)	<0.0001	47.25 (4.98)	90.00 (12.04) (N=8)	42.75	(31.21 to 54.29)	<0.0001
	Bilateral	46.09 (8.98)	66.98 (19.98) (N=49)	20.89	(15.48 to 26.31)	<0.0001	48.58 (10.34)	78.17 (19.20) (N=12)	29.58	(17.42 to 41.75)	<0.001
HHS≥60 points at baseline	Unilateral	82.77 (10.38)	84.60 (12.06) (N=114)	1.83	(-0.26 to 3.92)	0.08	82.67 (9.26)	86.30 (16.66) (N=30)	3.63	(-2.61 to 9.88)	0.24
	Bilateral	76.66 (9.13)	82.43 (15.33) (N=82)	5.77	(2.87 to 8.66)	<0.001	75.05 (9.33)	84.29 (14.58) (N=21)	9.24	(2.07 to 16.41)	0.01
HHS<60 points at baseline											
Unilateral: K/L grade1(N=10), K/L grade2 (N=8), K/L grade 3 (N=11), K/L grade 4 (N=8)											
Angle in a modified Patrick's test: <30° (N=2, ≥30° (N=30)											
Bilateral: K/L grade1 (N=11), K/L grade 2 (N=13), K/L grade 3 (N=15), K/L grade 4 (N=8)											
Angle in a modified Patrick's test: <30° (N=3, ≥30° (N=32)											
HHS≥60 points at baseline											
Unilateral: K/L grade 1 (N=47), K/L grade 2 (N=24), K/L grade 3 (N=29), K/L grade 4 (N=13)											
Angle in a modified Patrick's test: <30° (N=7), ≥30° (N=71)											
Bilateral: K/L grade 1 (N=40), K/L grade 2 (N=16), K/L grade 3 (N=18), K/L grade 4 (N=8)											
Angle in a modified Patrick's test: <30° (N=5), ≥30° (N=60)											
Parenthesis were SD											
Two sided p<0.05 was significant											

Table 2e: HHS in accordance with HHS<60 points or HHS ≥ 60points at baseline p<0.05.

Changes in SF-36 scores

Changes from baseline to 3 months follow-up: The results of all investigated patients are shown in Tables 2f and 2g. In the Unilateral OA group, patients with an HHS below 60 points at baseline had significant improvements in their Mental Component summary score. In the Bilateral OA group, patients with an HHS below 60 points at baseline had significant improvements in their Mental Component and Role/Social Component summary scores (Tables 2h and 2i). Tables 2h and 2i show the results of patients with a baseline HHS above 60 points.

Changes from baseline to 1-year follow-up: The results of all investigated patients are shown in Tables 2f and 2g. Patients in the Unilateral OA and Bilateral OA groups with an HHS below 60 points at baseline had no significant changes in any of the component summary scores between baseline and 1-year follow-up (Tables 2h and 2i). Tables 2h and 2i show the results of patients with a baseline HHS above 60 points.

Discussion

Pelvic malalignment must be corrected and decontracture of the

	Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 year)	1 year	Mean (95% confidence interval)		P value
Physical Functioning (NBS)	33.83 (15.93)	35.52 (14.71) (n=114)	1.68	(-0.49 to 3.85)	0.13	35.80 (11.08)	38.12 (11.80) (n=28)	2.32	(-2.28 to 6.93)	0.31
Role Physical (NBS)	39.01 (14.26)	41.42 (14.12) (n=113)	2.41	(-0.19 to 5.01)	0.07	40.64 (12.7)	42.31 (13.81) (n=28)	1.67	(-3.22 to 6.56)	0.49
Bodily Pain (NBS)	38.07 (8.67)	42.49 (8.40) (n=113)	4.42	(2.75 to 6.09)	<0.0001	39.37 (10.01)	44.85 (7.54) (n=27)	5.48	(1.29 to 9.66)	0.01
General Health (NBS)	45.69 (10.25)	47.47 (9.44) (n=114)	1.78	(0.36 to 3.20)	0.01	46.30 (9.28)	47.69 (8.52) (n=28)	1.39	(-1.27 to 4.05)	0.29
Vitality (NBS)	45.98 (11.00)	49.24 (9.48) (n=114)	3.26	(1.61 to 4.91)	<0.001	48.10 (13.07)	49.26 (9.66) (n=28)	1.16	(-1.95 to 4.26)	0.45
Social Functioning (NBS)	45.59 (12.39)	47.96 (11.48) (n=114)	2.38	(0.18 to 4.58)	0.03	45.96 (11.21)	49.87 (9.34) (n=28)	3.91	(-0.13 to 7.96)	0.06
Role Emotional (NBS)	43.78 (14.03)	46.42 (13.13) (n=112)	2.64	(0.11 to 5.17)	0.04	46.06 (11.92)	48.23 (11.28) (n=27)	2.16	(-1.36 to 5.69)	0.22
Mental Health (NBS)	47.74 (10.78)	50.51 (9.80) (n=114)	2.77	(1.08 to 4.47)	0.002	49.61 (11.22)	52.12 (10.02) (n=28)	2.51	(-1.27 to 6.30)	0.18
Physical Component summary score	34.18 (13.14)	35.58 (11.59) (n=110)	1.4	(-0.59 to 3.40)	0.17	35.64 (9.52)	36.43 (11.15) (n=26)	0.8	(-3.14 to 4.73)	0.68
Mental Component summary score	50.64 (10.12)	53.51 (8.50) (n=110)	2.87	(1.47 to 4.28)	<0.0001	51.67 (11.93)	53.72 (10.52) (n=26)	2.04	(-1.09 to 5.17)	0.19
Role-Social Component summary score	46.46 (15.56)	47.84 (13.84) (n=110)	1.37	(-1.33 to 4.08)	0.32	47.99 (12.76)	49.59 (13.68) (n=26)	1.6	(-2.77 to 5.98)	0.46
Parenthesis were SD										
Two-sided p<0.05 was siginificant										

Table 2f: Difference in SF-36 scores at baseline and follow-up at 3 months and 1 year (Unilateral OA group, NBS; Norm-Based Scoring).

	Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 year)	1 year	Mean (95% confidence interval)		P value
Physical Functioning (NBS)	29.32 (15.17)	33.13 (15.91 (n=103)	3.81	(1.66 to 5.96)	<0.001	31.92 (11.04)	36.45 (12.56) (n=28)	4.52	(1.19 to 7.86)	0.01
Role Physical (NBS)	34.87 (14.16)	38.79 (14.33 (n=102)	3.93	(1.52 to 6.34)	0.002	37.08 (14.17)	41.48 (13.41) (n=28)	4.4	(-0.41 to 9.20)	0.07
Bodily Pain (NBS)	35.70 (7.70)	41.14 (7.71 (n=102)	5.44	(3.87 to 7.01)	<0.0001	34.97 (7.55)	42.00 (6.48) (n=28)	7.03	(3.29 to 10.77)	<0.001
General Health (NBS)	44.59 (8.72)	46.71 (8.87 (n=102)	2.13	(0.97 to 3.28)	<0.001	44.71 (9.95)	48.51 (10.42) (n=28)	3.8	(1.32 to 6.28)	0.004
Vitality (NBS)	44.23 (9.11)	46.81 (9.83 (n=102)	2.58	(0.77 to 4.40)	0.006	44.90 (8.62)	49.49 (8.63) (n=28)	4.59	(0.43 to 8.75)	0.03
Social Functioning (NBS)	42.41 (13.68)	45.51 (12.09 (n=102)	3.09	(1.04 to 5.15)	0.004	44.34 (13.30)	48.95 (11.18) (n=28)	4.6	(-0.48 to 9.69)	0.07
Role Emotional (NBS)	40.99 (14.23)	45.32 (12.57 (n=101)	4.33	(1.96 to 6.70)	<0.001	40.46 (15.15)	47.16 (13.83) (n=28)	6.7	(1.59 to 11.81)	0.01
Mental Health (NBS)	46.38 (10.48)	50.78 (9.21 (n=102)	4.4	(2.58 to 6.21)	<0.0001	47.42 (9.07)	52.50 (7.59) (n=28)	5.08	(1.43 to 8.72)	0.008
Physical Component summary score	30.95 (11.51)	33.91 (12.92 (n=101)	2.97	(1.10 to 4.83)	0.002	31.68 (9.78)	35.31 (10.70) (n=28)	3.63	(0.89 to 6.37)	0.01
Mental Component summary score	50.79 (8.63)	53.03 (8.12 (n=101)	2.24	(0.64 to 3.83)	0.006	50.81 (8.74)	54.66 (8.75) (n=28)	3.85	(0.24 to 7.47)	0.04
Role-Social Component summary score	43.14 (16.07)	46.52 (14.15 (n=101)	3.38	(0.91 to 5.85)	0.008	44.43 (17.13)	48.76 (14.95) (n=28)	4.34	(-1.38 to 10.06)	0.13
Parenthesis were SD										
Two-sided p<0.05 was siginificant										

Table 2g: Difference in SF-36 scores at baseline and follow-up at 3 months and 1 year (Bilateral OA group, NBS; Norm-Based Scoring).

		Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 year)	1 year	Mean (95% confidence interval)		P value
HHS<60 points at baseline	Physical Component summary score	30.56 (9.88)	32.70 (11.64) (N=31)	2.14	(-0.69 to 4.97)	0.13	37.43 (8.21)	33.73 (10.55) (N=6)	-3.70	(-12.03 to 4.63)	0.31
	Mental Component summary score	48.63 (8.47)	51.76 (7.57) (N=31)	3.13	(0.57 to 5.70)	0.02	46.42 (5.19)	49.13 (8.32) (N=6)	2.72	(-2.67 to 8.10)	0.25
	Role-Social Component summary score	44.84 (15.54)	46.53 (14.59) (N=31)	1.70	(-3.29 to 6.69)	0.49	50.30 (14.22)	59.87 (6.05) (N=6)	9.57	(-6.59 to 25.72)	0.19
HHS≥60 points at baseline	Physical Component summary score	36.55 (12.84)	37.48 (10.50) (N=77)	0.93	(-1.71 to 3.56)	0.49	35.10 (10.01)	37.25 (11.46) (N=20)	2.15	(-2.54 to 6.83)	0.35
	Mental Component summary score	51.35 (10.74)	54.02 (8.81) (N=77)	2.67	(0.92 to 4.43)	0.003	53.25 (13.00)	55.09 (10.89) (N=20)	1.84	(-2.13 to 5.81)	0.34
	Role-Social Component summary score	47.69 (15.21)	49.09 (12.84) (N=77)	1.40	(-1.96 to 4.76)	0.41	47.29 (12.60)	46.51 (13.90) (N=20)	-0.79	(-4.59 to 3.02)	0.67
Parenthesis were SD											
Two-sided p<0.05 was significant											

Table 2h: SF-36 scores in accordance with HHS<60 points or HHS≥60points at baseline (Unilateral OA group, NBS; Norm-Based Scoring).

		Baseline	3 months	Mean (95% confidence interval)		P value	Baseline (1 year)	1 year	Mean (95% confidence interval)		P value
HHS<60 points at baseline	Physical Component summary score	28.39 (10.48)	28.93 (11.30) (N=31)	0.54	(-2.90 to 3.97)	0.75	29.81 (10.07)	31.77 (13.60) (N=10)	1.96	(-3.53 to 7.45)	0.44
	Mental Component summary score	50.02 (7.98)	53.32 (9.21) (N=31)	3.30	(0.92 to 5.68)	0.008	50.56 (6.27)	54.66 (9.07) (N=10)	4.10	(-2.53 to 10.73)	0.2
	Role-Social Component summary score	35.94 (16.50)	43.57 (12.79) (N=31)	7.64	(2.42 to 12.85)	0.006	39.64 (18.13)	44.31 (11.71) (N=10)	4.67	(-7.30 to 16.64)	0.4
HHS≥60 points at baseline	Physical Component summary score	32.08 (11.84)	36.12 (13.05) (N=70)	4.04	(1.82 to 6.27)	<0.001	32.71 (9.75)	37.27 (8.51) (N=18)	4.56	(1.20 to 7.92)	0.01
	Mental Component summary score	51.14 (8.94)	52.91 (7.67) (N=70)	1.77	(-0.30 to 3.84)	0.09	50.94 (10.02)	54.66 (8.83) (N=18)	3.72	(-1.06 to 8.49)	0.12
	Role-Social Component summary score	46.33 (14.90)	47.82 (14.61) (N=70)	1.49	(-1.20 to 4.19)	0.27	47.09 (16.46)	51.24 (16.26) (N=18)	4.15	(-2.84 to 11.14)	0.23
Parenthesis were SD											
Two-sided p<0.05 was siginificant											

Table 2i: SF-36 scores in accordance with HHS<60 points or HHS≥60points at baseline (Bilateral OA group, NBS; Norm-Based Scoring).

affected hip must be performed to decrease motion pain, thus improving function in patients with OA of the hip and an HHS below 60 points. In this study, PSTR exercises were not indicated for patients with a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test. Patient education including ADL instruction is essential for PSTR exercises to be effective and to maintain adequate function and QOL over the long term [29-32].

Continuation of exercises

Once symptoms improved, patients had difficulty continuing all of the PSTR exercises daily as preventive treatment. Even if pelvic balance was restored, once patients with prolonged symptoms stopped performing the pelvic realignment exercise, the anterior pelvic tilt and elevation of the greater trochanter on the affected side tended to recur within a few days. Therefore, the following treatment program was implemented after the first 3 months of PSTR exercises.

Three months from baseline

If anterior pelvic tilt and elevation of the greater trochanter were alleviated and symptoms improved

1. Patients temporarily stopped performing the pelvic alignment exercise. If the anterior pelvic tilt and elevation of the greater trochanter were absent for 2 weeks, patients discontinued the pelvic realignment exercise. Patients continued to perform the exercise to correct apparent leg-length differences and the back-and-forth exercise. Instructors followed patients for up to 1 year from baseline.
2. If anterior pelvic tilt and elevation of the greater trochanter recurred within 2 weeks, patients continued to perform the pelvic alignment exercise for 3 more months.

If anterior pelvic tilt and elevation of the greater trochanter were alleviated but symptoms did not improve: Instructors re-evaluated the program and re-educated the patient regarding ADL. If the patient had a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test, instructors considered THA in consultation with an orthopedic surgeon. A SIF of the femoral head or massive tearing of the capsule, labrum, and pericapsular ligaments may be present in these cases.

If the anterior pelvic tilt and elevation of the greater trochanter remained and symptoms did not improve: Patients continued to perform the pelvic realignment exercise. If the patient had a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test, instructors considered THA in consultation with an orthopedic surgeon.

If the anterior pelvic tilt and elevation of the greater trochanter remained but symptoms improved: Patients continued to perform the pelvic realignment exercise. Symptoms could readily recur; surgery (osteotomy, THA, etc.) was considered when symptoms recurred if the anterior pelvic tilt and elevation of the greater trochanter remained. THA was considered for patients with a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test.

Six months from baseline

If anterior pelvic tilt and elevation of the greater trochanter were alleviated and symptoms improved: After performing the pelvic realignment exercise for 6 months, almost all patients had improvement of anterior pelvic tilt and greater trochanter elevation, with alleviation of symptoms. Patients stopped performing the pelvic realignment exercise but continued to perform the exercise to correct apparent leg-length differences and the back-and-forth exercises. Instructors followed patients for up to 1 year from baseline.

Patients performed PSTR exercises only as home exercises; instruction during clinic visits stopped. Patients who determined that elevation of the greater trochanter had recurred visited the clinic for reevaluation by instructors. Therefore, instruction in self-evaluation of the greater trochanter on the affected side was important (Supplementary Information). When the greater trochanter was difficult to locate, the position of the medial malleolus of the ankles was compared [20]. The medial malleolus of the ankle on the affected side is often elevated proximally in patients with hip pain. Patients cannot compare the position of the medial malleolus of their own ankles, so family members were taught this technique.

If anterior pelvic tilt and elevation of the greater trochanter were alleviated but symptoms did not improve: Instructors re-evaluated the program and reeducated the patient regarding ADL. THA was considered in patients with a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test.

If anterior pelvic tilt and elevation of the greater trochanter remained and symptoms did not improve: Instructors re-evaluated the program and patients continued to perform the pelvic realignment exercise for 6 more months. THA was considered in patients with a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test.

If the anterior pelvic tilt and elevation of the greater trochanter remained and symptoms did improve: Patients continued to perform the pelvic realignment exercise. Symptoms could readily recur; surgery (osteotomy, THA, etc.) was considered when symptoms recurred and the anterior pelvic tilt and elevation of the greater trochanter remained. THA was considered for patients with a KL grade of 4 and an opening angle of the hip smaller than 30° according to a modified Patrick's test.

One year from baseline

If symptoms improved: Patients continued to perform the back-and-forth exercise.

If symptoms did not improve: Surgery (osteotomy, THA, etc.) was considered. If patients wanted to continue performing the exercises, instructors reevaluated the program and re-educated the patient regarding ADL for up to 2 years from baseline.

Two years from baseline

If symptoms improved

Patients continued to perform the back-and-forth exercise.

If symptoms did not improve: Surgery (osteotomy, THA, etc.) was considered.

The Mental Component and Role/Social Component summary scores on the SF-36 improved in both the Unilateral OA and Bilateral OA groups to near 50 points according to norm-based scoring. However, the Physical Component summary score improved only slightly, remaining below 50 points according to norm-based scoring (Tables 2f and 2g).

Low back pain may have contributed to the low Physical Component summary scores. A lumbosacral disturbance or a sacroiliac disturbance may have been involved [18,21]. The current authors plan to develop new exercises to address these issues and to establish guidelines for the timing of hip surgery based on screening involving PSTR exercises.

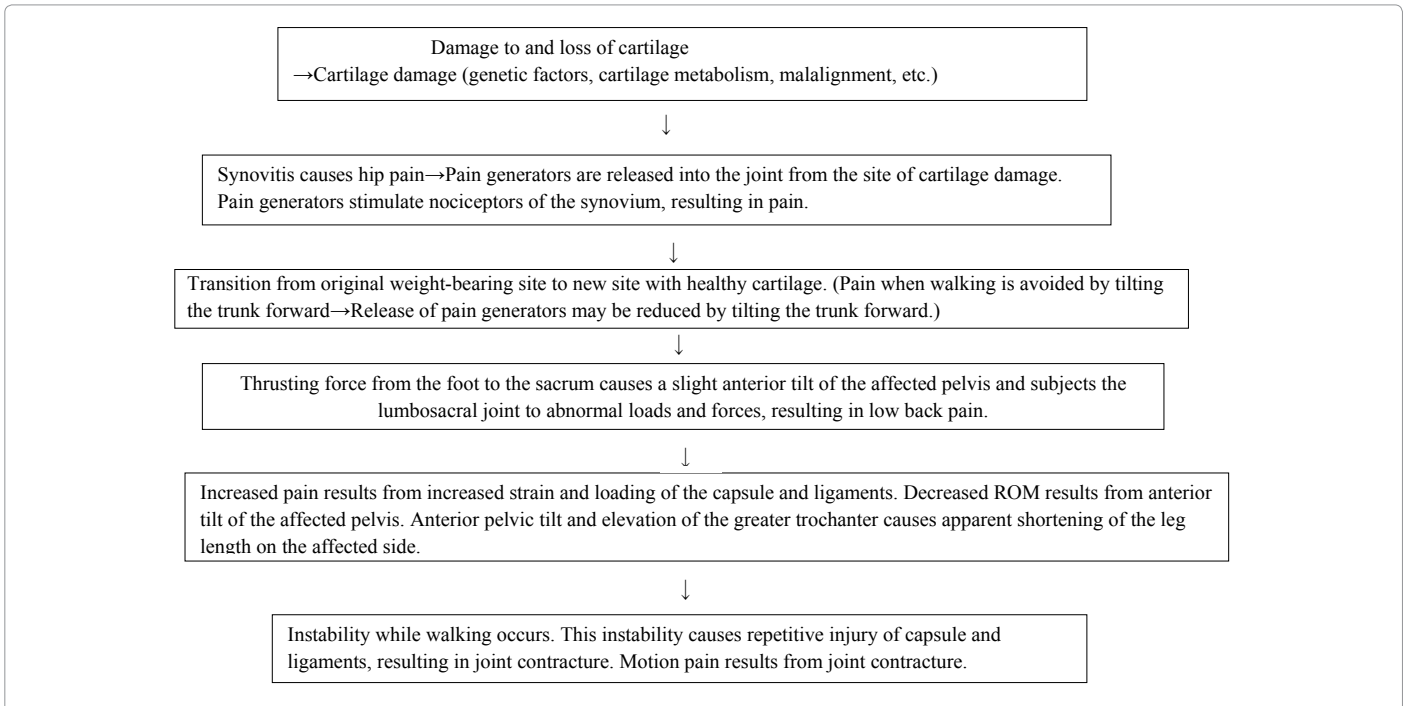

Figure 3: Discussion of the development of pain in patients with osteoarthritis of the hip.

Motion pain as mechanism for hip pain

In many of the current patients, symptoms improved markedly as a result of PSTR exercises, even in patients with loss of joint cartilage. Partial or total loss of cartilage is not directly related to hip pain, but it can trigger that pain. Excessive strain on or overloading of the synovium, periosteum, capsule, ligaments, and labrum may cause hip pain *via* the mechanism shown in Figure 3 [33]. Anterior pelvic tilt and elevation of the greater trochanter may cause an apparent leg-length difference in the affected hip, resulting in instability while walking. This instability may cause repetitive PST injury, resulting in joint contracture. According to several studies, the main cause of joint contracture is skeletal muscle, followed by the joint capsule; other studies have also mentioned ligament contracture [34-38]. Therefore, performing PSTR exercises early to improve apparent leg-length differences and contracture of the joint capsule and ligaments is crucial to alleviate hip pain in motion and to prevent progression of OA. Ligament contracture needs to be studied in the future. In this new perspective, pericapsular soft tissue must be considered a pain generator in OA of the hip that can be addressed with new home exercises to prevent surgery [39].

This retrospective study revealed that a new home exercise program may improve hip function for patients with OA of the hip and an HHS below 60 points. We have begun a multicenter prospective single-arm study to confirm the effectiveness of this program [40]. In addition we plan studies to investigate the decontracture test to differentiate between motion pain and walking pain to determine surgical indications [39].

Strengths and Limitations

This study appears to be the first to describe an attempt to develop effective physical therapy for patients with severe OA of the hip (including those with an HHS below 60 points) who wish to postpone or avoid surgery for a prolonged period. However, there is no conclusive evidence of the effectiveness of PSTR exercises because this was a retrospective observational study with no controls.

Patients who took analgesics (even if only once) were excluded because this was a retrospective observational study. However, including patients who took analgesics with no change in type or dose would result in fewer drop-outs 1 year from baseline. The current authors plan to design a prospective comparative study that includes patients who take analgesics with no change in type or dose. Patients who received chiropractic treatment or other hip therapy at baseline were also excluded because this was a retrospective observational study. Patients had difficulty continuing to perform PSTR exercises for longer than 1 year. As mentioned in the discussion, the current authors plan to create a greatly reduced exercise program for patients whose symptoms improve (alleviation of anterior pelvic tilt and elevation of the greater trochanter) and to establish an exercise program to prevent surgery. Patients who were excluded from this study as described in the steps for patient enrollment in Figure 3 were determined based on a retrospective analysis of interviews in which a patient met two or more of the exclusion criteria. In Table 1, the Unilateral OA group at baseline consisted of 154 patients; however, two patients were eliminated because some of the data on their HHS scores were missing.

Comparison to Other Studies

To our knowledge, the current study is the first to analyze the effectiveness of exercise therapy to postpone or prevent surgery for a prolonged period in patients with severe symptoms of OA, including those with an HHS below 60 points. According to the latest Cochrane review, patients generally perform land-based exercise programs consisting of traditional muscle strength training, functional training, or an aerobic fitness program [1], except for one study in which participants were enrolled in a tai chi program [3]. The current study is the first to investigate the effectiveness of a pelvic realignment exercise before muscle exercises to improve function in patients with OA of the hip. We plan to conduct a prospective comparative study to investigate the relationship between the effect of PSTR exercises and changes in pelvic malalignment over time.

Author Contributions

K. Hayashi contributed to study design, collection, analysis, and interpretation of data, and drafting and revising of the manuscript. S. Tokunaga contributed to analysis and interpretation of data, use of statistics, and critical revising of the manuscript. K. Haruguchi, D. Nakaniwa, and Y. Tobo contributed to the explanations of PSTR exercises, the discussion, and analysis of patient characteristics at baseline (Table 1). T Shimose contributed to analysis and interpretation of data and use of statistics. All authors approved the final version of the manuscript.

Ethical Considerations and Study Approval

The study was carried out in accordance with the Helsinki Declaration and was approved by the Fukuoka Wajiro Hospital medical research ethics committee.

Earlier Publication

Some of the results of this study were prepared as an abstract and poster at the 2015 OARSI World Congress, April 30-May 3, 2015 in Seattle, WA, USA [41].

Conflict of Interest

None

Acknowledgments

PSTR exercise is a part of the Yuki program developed by Teruo Ooyati (Osaka, Japan) [41]. K. Hayashi treated patients with OA of the hip using an open kinetic chain exercise to strengthen the hip abductors of the gluteus medius and stretching from 1998 to 2006. This open kinetic chain exercise involves raising and lowering the leg and stretching on the affected side but did not alleviate symptoms or improve function in patients with an HHS below 60 points. In 2007, K. Hayashi introduced PSTR exercises that T. Ooyati had developed over a 20 year period, and achieved alleviation of symptoms and improvement in function. The authors wish to thank the exercise developer T Ooyati as well as the staff of Yuki Shiatsu for their contributions. The authors wish to thank the staff of the Department of Rehabilitation of Fukuoka Wajiro Hospital in addition to K Haruguchi, D Nakaniwa, and Y Tobo for the contributions to the explanation and discussion of PSTR exercises and analysis of patient characteristics at baseline. Ken Toyota, director of the Clinical Research Support Center Kyushu, helped with supervisory advice regarding statistical analysis. The authors also wish to thank all 1,077 patients who participated in this study. We thank Rebecca Tollefson, DVM, from Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

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