Gait- and Posture-Related Factors Associated With Changes in Hip Pain and Physical Function in Patients With Secondary Hip Osteoarthritis: A Prospective Cohort Study

Authors:

Hiroshige Tateuchi, PT, PhD[1]*, Haruhiko Akiyama, MD, PhD[2], Koji Goto, MD, PhD[3], Kazutaka So, MD, PhD[4], Yutaka Kuroda, MD, PhD[3], Noriaki Ichihashi, PT, PhD[1]

[1] Department of Preventive Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan

[2] Department of Orthopaedic Surgery, School of Medicine, Gifu University, Gifu, Japan

[3] Department of Orthopaedic Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan

[4] Department of Orthopaedic Surgery, Osaka Red Cross Hospital, Osaka, Japan

[5] Department of Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University, Kyoto, Japan

*** Corresponding author:**

Hiroshige Tateuchi, Ph.D.

Associate Professor, Department of Preventive Physical Therapy, Human Health Sciences, Graduate School of Medicine, Kyoto University

53 Kawara-cho, Shogoin, Sakyo-ku, Kyoto 606-8507, Japan

Tel; +81-75-751-3948: Fax; +81-75-751-3948

E-mail; tateuchi.hiroshige.8x@kyoto-u.ac.jp

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ABSTRACT

Objective: To identify gait- and posture-related factors associated with changes in hip pain and physical function in patients with hip osteoarthritis (OA).

Design: Prospective cohort study

Setting: Clinical biomechanics laboratory of a university

Participants: Consecutive sample of 30 female patients with mild-to-moderate secondary hip OA.

Main Outcome Measures: Hip pain (visual analog scale) and physical function (physical component summary of the 36-Item Short Form Health Survey) were measured at baseline and 12 months later. With changes in hip pain and physical function as dependent variables, linear regression analyses were performed with gait- and posture-related factors as independent variables with and without adjustment for age, joint space width, and hip pain or physical function at baseline. Posture-related factors included angle of thoracic kyphosis, lumbar lordosis, sacral inclination, spinal inclination, and spinal mobility. Gait-related factors were gait speed, steps/day, and three-dimensional hip joint angles, external hip joint moment impulses, and daily cumulative hip moments.

Results: Multiple linear regression analyses showed that less hip extension (adjusted standardized *B* coefficient [95% CI]; −0.51 [−0.85 to −0.17]) and less external rotation angle (−0.52 [−0.88 to −0.17]) during gait were associated with worsening of hip pain. A larger thoracic kyphosis (−0.54 [−0.99 to −0.09]), less sacral anterior tilt (0.40 [0.01 to 0.79]), less thoracic spine mobility (0.59 [0.23 to 0.94]), less steps/day (0.53 [0.13 to 0.92]), and slower gait speed (0.45 [0.04 to 0.86]) were associated with deterioration of physical function.

Conclusions: Gait- and posture-related factors should be considered when assessing risk and designing preventive interventions for clinical progression of secondary hip OA.

(257words)

Keywords: Prognosis, Arthritis, Thoracic kyphosis, Spinal mobility, Physical activity

List of abbreviations:

ICC; intraclass correlation

JSW; joint space width

OA; osteoarthritis

RoM; range of motion

SF-36; 36-Item Short Form Health Survey

Hip osteoarthritis (OA) is characterized by hip pain and decline of physical function such as walking and structural changes. Joint pain and decline of physical function are critical issues as it leads to deterioration in patients' quality of life[1,2], and prevention of their progression remains a clinical challenge. To prevent clinical progression, the target of intervention should be clarified, i.e., identification of the risk factor of clinical progression is a priority.

In a systematic review and meta-analysis[3], additional knee OA, higher comorbidity count, lower level of physical activity, no supervised exercise, and lower level of education have been found as predictors for deterioration of the hip pain. However, this evidence is considered to be weak. For the deterioration of the physical function, higher comorbidity count and low vitality have been indicated as predictors with high evidence[3]. Additionally, study presented weak evidence that deterioration of physical function is predicted by poor general health, hip and knee pain, reduced hip and knee range of motion (RoM), and lower level of physical activity[3]. However, the predictors related to functional activities such as posture and gait that can be modified by exercise therapy remain to be investigated.

Changes in standing posture and gait generally occur as stage of hip OA progresses. Pelvic anterior tilt, lumbar lordosis, and anterior inclination of the spine progress with hip OA progression, whereas they tend to be compensated by posterior pelvic shift and extension of the thoracic spine[4,5]. Patients with hip OA also show abnormalities in gait such as slow gait speed, short stride length, and decreased hip motions and hip joint moments in three dimensions[6,7]. Gait- and posture-related factors such as inclination of the spine in standing and excessive hip loading during gait have been shown to be associated with radiographic progression of hip OA[8,9]. Clinical progression is not necessarily related to the radiographic progression in OA[10]. However, in healthy elderly people, anterior inclination of the spine in standing is associated with future decline in activities of daily living[11]. Furthermore, in patients with knee OA, lower gait speed is a predictor of deterioration of clinical performance measures[12], and kinematic changes in the knee during ambulation (e.g. varus thrust) are associated with knee pain[13]. Although these reports are targeted to people who are different from the subjects of this study, these suggest that gait and posture are associated with deterioration of joint pain and physical function. No studies investigating the association between gait- and posture-related factors and clinical progression in patients with hip OA have been conducted. Finding factors associated with deterioration of the hip pain and physical function among gait- and posture-related factors will give a novel viewpoint to clinicians aiming at prevention of clinical progression of hip OA.

This study aimed to identify the gait- and posture-related factors associated with changes in hip pain and physical function in patients with secondary hip OA in the cohort study. We hypothesized that spinal malalignment, reduced spinal mobility, and hip kinematic change during gait are associated with future deterioration of hip pain and physical function.

Methods

Participants

Patients diagnosed with secondary hip OA were selected from the department of orthopaedic surgery at university hospital. Patients were consecutively recruited from April 2013 to March 2015. A total of 30 patients were eligible for inclusion and were measured at baseline. All patients provided informed consent, and the protocol involving contacting for remeasurement was approved by the institutional review board. The inclusion criteria were as follows: (1) a diagnosis of pre-osteoarthritis (acetabular dysplasia with no other abnormal radiographic findings) or early (slight joint space narrowing [2 mm or more] and abnormal subchondral sclerosis) or advanced-stage hip OA (marked joint space narrowing [<2 mm] with or without cysts or sclerosis) hip OA and (2) ability to walk without any assistive device in daily life. The exclusion criteria were as follows: (1) a history of previous hip surgeries (e.g., osteotomy, arthroplasty) and (2) neurologic, vascular, or other conditions that seriously affect gait or activity of daily living. Because our sample was biased on sex (percentage of male patients; 7.1%), only female patients were included in this study.

Hip pain and physical function assessment

Hip pain severity was assessed on a 100-mm visual analog scale, where 0 was equal to no pain and 100 was equal to the worst pain imaginable. For the patients with bilateral hip OA, the side on which the radiographic OA change was more severe was used for analysis. Physical function was assessed using the Physical Component Summary of the Japanese version of 36-Item Short Form Health Survey version 2.0 (SF-36). The SF-36 is the most commonly used tool to assess health status in general and specific populations. The SF-36 has been shown to be reliable and valid in patients with OA[14,15], and it is particularly useful in patients with comorbidities[16]. Pain and physical function were assessed at baseline and 12 months later. In contrast, for the variables described below, values at baseline were used as independent variables.

Postural assessment

Details of postural and gait assessment were described elsewhere[8,9]. Briefly, spinal alignment in the sagittal plane was measured using the Spinal Mouse[a], which is a reliable and valid non-invasive device to measure spinal alignment and RoM[17–19]. The thoracic kyphosis angle (the sum of 11 segmental angles from Th1/2 to Th11/12), lumbar lordosis angle (the sum of 6 segmental angles from Th12/L1 to L5/S1), sacral inclination angle (the angle between straight line from S1 to S3 and vertical line), and spinal inclination angle (the angle between straight line from Th1 to S1 and vertical line) were measured in a relaxed standing position (Figure 1).

Spinal mobility was also measured using the Spinal Mouse. Thoracic kyphosis angle and lumbar lordosis angle were measured both at positions where the spine was maximally flexed and extended in sitting position. Absolute changes in thoracic kyphosis angle and lumbar lordosis angle between flexed and extended positions were calculated. Spinal alignment and mobility were measured thrice, and the mean value was used for analysis. The intrarater reliabilities [ICC (1,1)] for spinal alignment and mobility measurements were 0.86–0.99.

Gait assessment

Gait speed and hip kinematics and kinetics were measured using an 8-camera Vicon Motion System[b], at a sampling rate of 200 Hz with a fourth-order Butterworth Low-Pass filter (6 Hz), and using force plates[c], at a sampling rate of 1,000 Hz with a low-pass filter (20Hz). Patients were asked to walk barefoot at a self-selected speed without any assistive devices. A total of 20 reflective markers were affixed by a single experienced examiner. The pelvic, thigh, shank, and foot segments were constructed[8]. After several practice trials, 3 trials were recorded.

The three-dimensional hip joint angles and external hip joint moments for the affected limb were calculated using the BodyBuilder software[b]. The peak hip joint angles and hip joint moment impulses were calculated. Furthermore, daily cumulative hip moment was calculated by multiplying the hip joint moment impulse and the mean number of steps/day for the affected limb[8]. The daily cumulative hip moment represents the total amount of hip joint load in daily activity. The number of steps was recorded for 7 consecutive days within a month from the day of postural and gait assessment. Patients were asked to wear the pedometer[d] with high accuracy and validity[20,21] from waking until sleeping, and to send the record of the number of steps back to the examiner via mail. The value not normalized by body weight was used in hip joint moment impulse and daily cumulative hip moment because normalized value distracts attention from the actual loading on the joint though it is useful for group comparison of gait pattern[22]. In the gait-related factors, the mean values of 3 trials were calculated and used for analysis.

Other covariates

Demographic data were collected on age, height, and body weight. Radiographic assessment of the hip joint was performed using a digital supine anteroposterior radiograph of the pelvis. The minimum joint space width (JSW) was measured as an indicator of radiographic disease severity[8]. Images were reviewed and measured by a single experienced examiner using Centricity Enterprise Web, version 3.0[e]. The ICC (1,1) of JSW measurement was 0.99. As another potential predictor, information on the number of musculoskeletal pain comorbidities (comorbidity count) other than the hip joint was obtained via an interview.

Statistical analysis

SPSS version 24.0[f] was used for statistical analysis. The histograms were used to visualize the distribution of the changes in hip pain and physical function. To identify factors associated with future deterioration of hip pain and physical function, linear regression analyses were performed with gait- and posture-related factors at baseline as independent variables and absolute changes in hip pain and physical function as dependent variables. Furthermore, multiple linear regression analyses were performed with potential covariates. In the multivariable analysis, age, minimum JSW, comorbidity count, and hip pain at baseline were included as potential covariates for the change in hip pain, while age, minimum JSW, comorbidity count, and physical function at baseline were included for the change in physical function. Since body mass index has been confirmed not to be a predictor of deterioration of hip pain and physical function[3] and to examine the influence of gait-related factors not normalized by body weight, the factor related to body mass (i.e., body weight and body mass index) was not included as an independent variable. Variables correlated at absolute coefficients >0.7 were defined as multicollinearity[23]. The 30 patients included in this study fulfilled the required number of subjects per variable for linear regression analyses[24]. A P value <0.05 was considered statistically significant.

Results

Histograms showing distributions of changes in hip pain and physical function over 12 months were shown in Figure 2. Variations were found among patients; in particular, the change in physical function was widely distributed in both direction of deterioration and improvement.

Table 1 shows the baseline characteristics of the patients. Table 2 represents the results of univariable and multivariable regression analyses for deterioration of hip pain. There was no predictor in posture-related factors; however, less hip external rotation angle during gait was found to be a factor associated with deterioration of hip pain with and without adjustment for age, minimum JSW, comorbidity count, and hip pain at baseline. The less hip extension angle was also associated with deterioration of hip pain after adjustment for covariates. For the change in physical function (Table 3), larger thoracic kyphosis and less thoracic spine mobility were found to be factors associated with deterioration of physical function with and without adjustment for age, minimum JSW, comorbidity count, and physical function at baseline. Additionally, less sacral anterior tilt was associated with deterioration of physical function after adjustment for covariates. Furthermore, in the gait-related factors, less steps/day was associated with deterioration of physical function with and without adjustment, and slower gait speed was also associated with deterioration of physical function after adjustment. There was no multicollinearity between variables.

Discussion

This prospective cohort study revealed that (1) the less hip extension and external rotation angle during gait were factors associated with worsening of hip pain, and (2) larger thoracic kyphosis, less sacral anterior tilt, less thoracic spine mobility, less steps/day, and slower gait speed were associated with decline of physical function. The findings generally support our hypothesis.

Studies investigating the association between functional impairment and clinical progression of hip OA are very limited. Some cohort studies have found that reduced RoM of the hip flexion, external rotation, and knee extension were associated with clinical progression of hip OA[25–27]. Pisters et al.[28] reported that reduced hip abduction muscle strength mediates the relationship between avoidance of activity and limitations in daily activities. However, investigations are lacking regarding the relationship between clinical progression of hip OA and standing posture and gait, which are most frequently used in daily activities and suspected to be related to the progress of joint symptom and physical function. The novel findings in this study will contribute to clarifying therapeutic targets for clinicians who provide therapy aimed at prevention of clinical progression of hip OA.

Only the hip kinematic changes during gait were found as a predictor for deterioration of hip pain. Although conflicting results were reported for hip external rotation angle[29,30], reduced hip extension angle during gait is a phenomenon most commonly seen in patients with hip OA even in mild-to-moderate hip OA[29–31] and in hip dysplasia[32]. Hip joint stress increases in the later stance phase when the hip joint is in the extended position[33] and the iliofemoral ligament is stretched in the hip extended and external rotated positions[34]. In cross-sectional studies, reduced hip extension during gait has been reported to be associated with reduced passive hip extension RoM[35] and cartilage lesion of the femur[36]. These previous studies suggest that patients who show reduced hip extension (and possibly reduced hip external rotation) during gait potentially have altered joint structures and impaired stabilizing mechanism of the hip. Patients with such conditions cannot extend their hip during gait due to structural restraint, or hip pain would be exacerbated by extending the hip. This finding would provide clinicians with notable point in observational gait analysis for patients who need to prevent deterioration of hip pain.

Less physical activity (steps/day) and slower gait speed were found as factors associated with deterioration of physical function. These findings are consistent with those of other cohort studies on hip OA[25,37]. Moreover, larger thoracic kyphosis, less sacral anterior tilt, and less thoracic spine mobility were identified as factors associated with deterioration of physical function. Although no studies have investigated the relationship between posture and mobility of the spine and status of physical function of hip OA, changes in spinal alignment associated with hip OA has been reported. In general, sacral anterior tilt decreases with aging; however, it increases with the progression of hip OA secondary to hip dysplasia[4]. The sacral (i.e., pelvic) anterior tilt compensatory increases the coverage of the femoral head and could reduce the stress on the hip joint[38]. Patients with less sacral anterior tilt seem to have such a compensatory mechanism not functioning. Meanwhile, global sagittal malalignment of the spine with sacral anterior tilt tends to be compensated by reduced thoracic kyphosis. Indeed, thoracic kyphosis decreases in the standing posture with hip OA progression[5], and compensatory thoracic motion during gait increases in patients with hip OA than in asymptomatic people[39]. These reports on postural change in patients with hip OA suggest that less thoracic kyphosis and thoracic spine mobility is important to maintain the sagittal balance of the spine. Patients who have incongruence between the femoral head and acetabular due to less sacral anterior tilt and/or who have difficulties to compensate for the sagittal balance of the spine in the thoracic spine may be more likely have deterioration of physical function. It has been reported that exercise therapy focusing on spinal muscle strengthening and improving spinal mobility can reduce or delay the progression of hyperkyphosis even in middle-aged and elderly people[40–42]. Alignment and mobility of the spine would be a remarkable factor in preventing clinical progression of the hip OA as a modifiable predictor.

Interestingly, mechanical factors during gait such as hip joint moment during a gait cycle and daily total amount of hip loading were not associated with the clinical progression of hip OA, although daily cumulative hip moment is associated with radiographic progression of hip OA[8]. Similarly, in knee OA, although the increased knee joint moment during gait is considered as the risk factor of radiographic progression[43], it is not clearly recognized as a predictor of clinical progression of knee OA. It is well known that OA-related pain is activated not only by mechanical stimuli, but is also the result of a complex interaction between local tissue damage, inflammation, and the peripheral and central nervous system[44,45]. Thus, multifaceted nature of OA-related pain may draw the current result that mechanical factor during gait was not associated with change in hip pain.

Study limitations

Spinal alignment and mobility were measured only in the sagittal plane, and spinal motion during walking was not measured. Radiography and more detailed spinal motion analysis can approach the core of the impairments of posture and spinal motion. However, in consideration of clinical applicability, we chose a method that can be easily measured clinically and a general gait analysis. Sociodemographic factors such as education level and psychosocial factors such as cognitive function were not measured in this study and may also be potential predisposing factors of clinical progression though there is weak or inconsistent evidence that those factors are not predictive[3]. Therefore, further large investigations involving multiple factors are required. The follow-up period of 12 months was relatively short. Further long-term research may reveal different predictors. However, patterns of change in hip pain and physical function have large heterogeneity[46], which is not reduced by prolonging the follow-up period[3]. Verkleij et al[46]. classified patients with hip OA into 5 subgroups based on trajectories of hip pain during 2 years (i.e., mild pain, moderate pain, always in pain, regular progression, and high progression). Our research would show predictors of a “high progression” group which clearly worsens pain even in 12 months. The other potential limitation in the generalizability of the findings of this study should also be acknowledged although female participants and secondary hip OA included in this study comprise a majority in case of hip OA[47,48]. Despite these limitations, the finding of this study represents the first step to elucidate the mechanism of gait- and posture-related factors causing deterioration of symptom and physical function in patients with hip OA.

Conclusions

In conclusion, less hip extension and external rotation angle during gait were identified as factors associated with worsening of hip pain, and larger thoracic kyphosis, less sacral anterior tilt, less thoracic spine mobility, less steps/day, and slower gait speed were identified as factors associated with the decline of physical function. Because the gait- and posture-related factors can be modified by exercise therapy, these factors should be included as targets of future intervention studies for prevention of clinical progression of hip OA.

(2,995 words)

Suppliers:

a, Idiag AG, Mulistrasse 18, Fehraltorf 8320, Switzerland

b, Vicon Motion Systems Ltd, 6, Oxford Industrial Park, Yarnton, Oxford, OX5 1QU, England

c, Kistler Japan Co., Ltd, 3-20-8, Shinyokohama, Minatokita-ku, Yokohama, Kanagawa, Japan

d, EX-500, Yamasa Tokei Co., Ltd, 2-4-9, Kaminoge, Setagaya-ku, Tokyo, Japan)

e, GE Health care, Nightingales Lane, Chalfont Street Giles, Buckinghamshire, HP8 4SP, England

f, IBM Japan Ltd, 19-21, Nihonbashi, Hakozaki-cho, Chuo-ku, Tokyo, Japan

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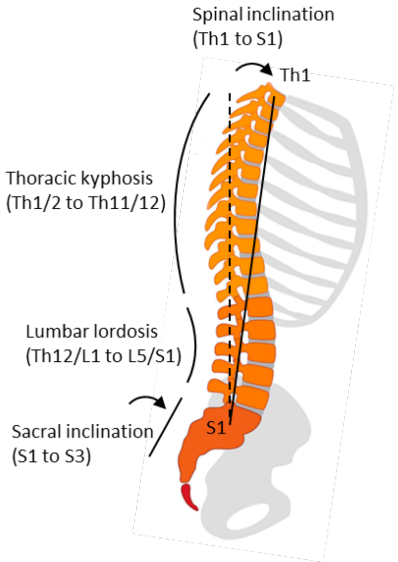

Fig 1. Angle of the thoracic kyphosis, lumbar lordosis, sacral inclination, spinal inclination, and spinal mobility were measured as posture-related factors.

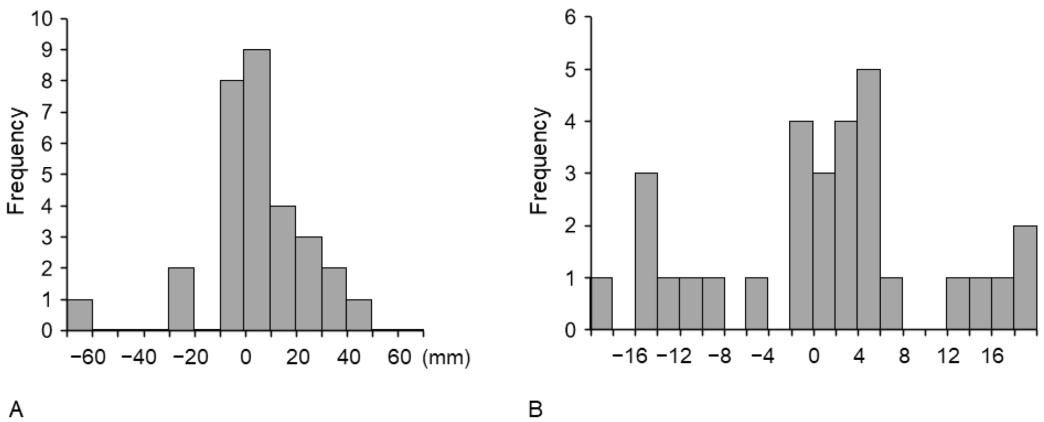

Fig 2. Distribution of absolute changes in hip pain (A) and physical function (B) between baseline and 12 months of follow-up.

Table 1. Demographic, radiographic, postural, and gait data at baseline.

	Mean	SD
Age, years	49.5	9.7
Height, cm	156.2	5.8
Weight, kg	54.6	10.3
Minimum joint space width, mm	3.23	1.51
Comorbidity count	1.0	0.8
Posture-related factor, degrees		
Thoracic kyphosis	43.0	11.0
Lumbar lordosis	31.1	10.8
Sacral inclination (+; anterior)	14.9	7.7
Spinal inclination (+; anterior)	1.5	2.3
Thoracic spine mobility	31.0	12.2
Lumbar spine mobility	51.0	12.0
Gait-related factor		
Steps/day	6,578.0	2,622.9
Gait speed, meters/seconds	1.12	0.19
Hip flexion angle, degrees	34.5	5.9
Hip extension angle, degrees	2.1	5.8
Hip abduction angle, degrees	9.7	3.2
Hip adduction angle, degrees	4.0	3.1
Hip external rotation angle, degrees	7.4	6.0
Hip internal rotation angle, degrees	11.9	6.7
Hip moment impulse (Flex/Ext), Nm seconds	8.3	2.7
Hip moment impulse (Abd/Add), Nm seconds	22.0	8.1
Hip moment impulse (ER/IR), Nm seconds	2.4	0.8
Cumulative hip moment (Flex/Ext), kNm seconds	26.9	12.1
Cumulative hip moment (Abd/Add), kNm seconds	72.0	41.2
Cumulative hip moment (ER/IR), kNm seconds	7.9	4.5

(Footnotes for Table 1)

Abbreviations: Flex, flexion; Ext, extension; Abd, abduction; Add, adduction; ER, external rotation; IR, internal rotation.

Table 2. Linear regression analysis predicting the deterioration of hip pain.

	Unstandardized Beta coefficient	Standardized Beta coefficient	P-value	Unstandardized Beta coefficient	Standardized Beta coefficient	P-value
	Crude			Adjusted*		
Age, years	0.15 (−0.67 to 0.98)	0.07 (−0.32 to 0.46)	0.709	–	–	–
Minimum joint space width, mm	0.49 (−4.87 to 5.83)	0.04 (−0.35 to 0.42)	0.854	–	–	–
Comorbidity count	6.19 (−3.76 to 16.15)	0.23 (−0.14 to 0.61)	0.213	–	–	–
Hip pain (VAS), mm	−0.21 (−0.50 to 0.08)	−0.27 (−0.64 to 0.10)	0.148	–	–	–
Physical function (PCS in SF-36)	0.11 (−0.71 to 0.93)	0.05 (−0.34 to 0.44)	0.787	–	–	–
Posture-related factor, degrees						
Thoracic kyphosis	−0.48 (−1.19 to 0.23)	−0.25 (−0.63 to 0.12)	0.178	−0.49 (−1.35 to 0.36)	−0.26 (−0.71 to 0.19)	0.244
Lumbar lordosis	−0.17 (−0.92 to 0.58)	−0.09 (−0.47 to 0.30)	0.647	−0.17 (−0.99 to 0.66)	−0.09 (−0.51 to 0.34)	0.677
Sacral inclination (+; anterior)	0.00 (−1.05 to 1.05)	0.00 (−0.39 to 0.39)	0.995	−0.13 (−1.21 to 0.95)	−0.05 (−0.45 to 0.35)	0.808
Spinal inclination (+; anterior)	−0.78 (−4.21 to 2.64)	−0.09 (−0.47 to 0.30)	0.643	−1.40 (−5.00 to 2.19)	−0.16 (−0.56 to 0.25)	0.429
Thoracic spine mobility	0.55 (−0.08 to 1.17)	0.32 (−0.05 to 0.69)	0.085	0.65 (−0.07 to 1.37)	0.38 (−0.04 to 0.80)	0.075
Lumbar spine mobility	−0.14 (−0.81 to 0.53)	−0.08 (−0.47 to 0.31)	0.680	−0.09 (−0.82 to 0.64)	−0.05 (−0.47 to 0.37)	0.801
Gait-related factor						
Steps/day†	−1.03 (−4.08 to 2.02)	−0.13 (−0.51 to 0.26)	0.496	−2.48 (−5.85 to 0.90)	−0.31 (−0.74 to 0.11)	0.143
Gait speed, meters/seconds	19.84 (−22.12 to 61.80)	−0.18 (−0.20 to 0.56)	0.341	−10.15 (−67.26 to 46.97)	−0.09 (−0.61 to 0.43)	0.717
Hip flexion angle, degrees	0.60 (−0.74 to 1.94)	0.17 (−0.21 to 0.55)	0.364	−0.54 (−0.82 to 1.91)	0.16 (−0.23 to 0.54)	0.418
Hip extension angle, degrees	−1.23 (−2.54 to 0.08)	−0.34 (−0.71 to 0.02)	0.065	**−1.89 (−3.17 to −0.60)**	**−0.52 (−0.88 to −0.17)**	**0.006**
Hip abduction angle, degrees	0.04 (−2.49 to 2.57)	0.01 (−0.38 to 0.39)	0.975	−0.07 (−2.71 to 2.84)	0.01 (−0.41 to 0.43)	0.961

Hip adduction angle, degrees	−1.08 (−3.62 to 1.47)	−0.16 (−0.54 to 0.22)	0.394	−2.63 (−5.37 to 0.12)	−0.39 (−0.81 to 0.02)	0.060
Hip external rotation angle, degrees	**−1.74 (−2.90 to −0.59)**	**−0.50 (−0.84 to −0.17)**	**0.004**	**−1.78 (−2.93 to −0.62)**	**−0.51 (−0.85 to −0.18)**	**0.004**
Hip internal rotation angle, degrees	0.71 (−0.46 to 1.88)	0.23 (−0.15 to 0.61)	0.226	0.70 (−0.55 to 1.95)	0.23 (−0.18 to 0.63)	0.257
Hip moment impulse (Flex/Ext), Nm seconds	−0.34 (−3.31 to 2.63)	−0.04 (−0.43 to 0.34)	0.817	−0.74 (−3.88 to 2.40)	−0.10 (−0.51 to 0.31)	0.630
Hip moment impulse (Abd/Add), Nm seconds	−0.42 (−1.41 to 0.56)	−0.16 (−0.55 to 0.22)	0.388	0.02 (−1.17 to 1.22)	0.01 (−0.46 to 0.47)	0.972
Hip moment impulse (ER/IR), Nm seconds	1.78 (−8.13 to 11.69)	0.07 (−0.32 to 0.46)	0.716	2.99 (−7.93 to 13.91)	0.12 (−0.31 to 0.54)	0.577
Cumulative hip moment (Flex/Ext), 10kNm seconds	−2.32 (−8.91 to 4.26)	−0.14 (−0.52 to 0.25)	0.476	−5.81 (−12.97 to 1.35)	−0.34 (−0.76 to 0.08)	0.107
Cumulative hip moment (Abd/Add), 10kNm seconds	−0.99 (−2.91 to 0.93)	−0.20 (−0.58 to 0.18)	0.300	−0.88 (−2.91 to 1.15)	−0.17 (−0.58 to 0.23)	0.380
Cumulative hip moment (ER/IR), 10kNm seconds	−1.85 (−19.74 to 16.04)	−0.04 (−0.43 to 0.35)	0.834	−4.89 (−24.85 to 15.06)	−0.11 (−0.54 to 0.33)	0.617

Table 2 (continued)

(Footnotes for Table 2)

The dependent variable is absolute change subtracting baseline value from 12 months later value (i.e., positive value represents deterioration of pain).

Value in parentheses is 95% confidence interval.

Significant associations are shown in bold.

Abbreviations: VAS, visual analogue scale; PCS, physical component summary; SF-36, 36-Item Short Form Health Survey; Flex, flexion; Ext, extension; Abd, abduction; Add, adduction; ER, external rotation; IR, internal rotation.

* Adjusted for age, minimum JSW, comorbidity count, and hip pain at baseline.

† Unit is 1,000 steps/day.

Table 3. Linear regression analysis predicting the deterioration of physical function.

	Unstandardized Beta coefficient	Standardized Beta coefficient	P-value	Unstandardized Beta coefficient	Standardized Beta coefficient	P-value
	Crude			Adjusted*		
Age, years	−0.14 (−0.55 to 0.27)	−0.14 (−0.52 to 0.25)	0.477	–	–	–
Minimum joint space width, mm	1.13 (−1.51 to 3.76)	0.16 (−0.22 to 0.55)	0.389	–	–	–
Comorbidity count	1.60 (−3.48 to 6.67)	−0.12 (−0.26 to 0.51)	0.525	–	–	–
Hip pain (VAS), mm	−0.09 (−0.24 to 0.06)	−0.23 (−0.61 to 0.14)	0.215	–	–	–
Physical function (PCS in SF-36)	−0.24 (−0.64 to 0.16)	−0.23 (−0.60 to 0.15)	0.231	–	–	–
Posture-related factor, degrees						
Thoracic kyphosis	**−0.39 (−0.73 to**	**−0.42 (−0.77 to −0.06)**	**0.022**	**−0.51 (−0.93 to −0.09)**	**−0.54 (−0.99 to −0.09)**	**0.020**
Lumbar lordosis	0.04 (−0.33 to 0.42)	0.05 (−0.34 to 0.43)	0.813	0.13 (−0.32 to 0.57)	0.13 (−0.33 to 0.59)	0.560
Sacral inclination (+; anterior)	0.38 (−0.12 to 0.88)	0.28 (−0.09 to 0.65)	0.134	**0.54 (0.01 to 1.07)**	**0.40 (0.01 to 0.79)**	**0.046**
Spinal inclination (+; anterior)	0.42 (−1.29 to 2.13)	0.09 (−0.29 to 0.48)	0.622	0.59 (−1.24 to 2.42)	0.13 (−0.28 to 0.54)	0.514
Thoracic spine mobility	**0.35 (0.05 to 0.65)**	**0.41 (0.06 to 0.76)**	**0.025**	**0.50 (0.20 to 0.80)**	**0.59 (0.23 to 0.94)**	**0.002**
Lumbar spine mobility	−0.11 (−0.44 to 0.22)	−0.13 (−0.51 to 0.26)	0.497	−0.11 (−0.49 to 0.27)	−0.13 (−0.56 to 0.31)	0.559
Gait-related factor						
Steps/day†	**1.61 (0.20 to 3.01)**	**0.41 (0.05 to 0.76)**	**0.026**	**2.08 (0.51 to 3.66)**	**0.53 (0.13 to 0.92)**	**0.012**
Gait speed, meters/seconds	11.39 (−9.45 to 32.23)	0.21 (−0.17 to 0.59)	0.272	**24.97 (2.43 to 47.51)**	**0.45 (0.04 to 0.86)**	**0.031**
Hip flexion angle, degrees	−0.27 (−0.94 to 0.40)	−0.15 (−0.54 to 0.23)	0.418	−0.20 (−0.89 to 0.49)	−0.11 (−0.51 to 0.28)	0.558
Hip extension angle, degrees	0.13 (−0.57 to 0.82)	0.07 (−0.32 to 0.46)	0.714	0.02 (−0.75 to 0.78)	0.01 (−0.41 to 0.43)	0.968
Hip abduction angle, degrees	−0.41 (−1.66 to 0.85)	−0.13 (−0.51 to 0.26)	0.511	−0.80 (−2.13 to 0.53)	−0.25 (−0.65 to 0.16)	0.225

Hip adduction angle, degrees	0.70 (−0.56 to 1.96)	0.21 (−0.17 to 0.59)	0.263	0.72 (−0.59 to 2.02)	0.22 (−0.18 to 0.61)	0.269
Hip external rotation angle, degrees	−0.15 (−0.82 to 0.51)	−0.09 (−0.47 to 0.30)	0.643	0.04 (−0.68 to 0.75)	0.02 (−0.40 to 0.44)	0.917
Hip internal rotation angle, degrees	−0.06 (−0.66 to 0.54)	−0.04 (−0.43 to 0.35)	0.840	−0.20 (−0.84 to 0.44)	−0.13 (−0.54 to 0.29)	0.528
Hip moment impulse (Flex/Ext), Nm seconds	−1.07 (−2.50 to 0.36)	−0.28 (−0.65 to 0.09)	0.136	−0.98 (−2.66 to 0.71)	−0.25 (−0.69 to 0.18)	0.242
Hip moment impulse (Abd/Add), Nm seconds	0.08 (−0.42 to 0.58)	0.06 (−0.33 to 0.45)	0.755	0.11 (−0.46 to 0.68)	0.09 (−0.36 to 0.53)	0.691
Hip moment impulse (ER/IR), Nm seconds	−1.38 (−6.31 to 3.55)	−0.11 (−0.49 to 0.28)	0.571	−1.85 (−7.46 to 3.75)	−0.15 (−0.58 to 0.29)	0.502
Cumulative hip moment (Flex/Ext), 10kNm seconds	2.22 (−0.99 to 5.42)	0.26 (−0.12 to 0.63)	0.168	3.47 (−0.26 to 7.21)	0.41 (−0.03 to 0.84)	0.067
Cumulative hip moment (Abd/Add), 10kNm seconds	0.57 (−0.38 to 1.53)	0.23 (−0.15 to 0.60)	0.227	0.70 (−0.32 to 1.72)	0.28 (−0.13 to 0.68)	0.171
Cumulative hip moment (ER/IR), 10kNm seconds	5.31 (−3.39 to 14.01)	0.23 (−0.15 to 0.61)	0.222	6.87 (−3.30 to 17.04)	0.30 (−0.14 to 0.74)	0.176

Table 3 (continued)

(Footnotes for Table 3)

The dependent variable is absolute change subtracting baseline value from 12 months later value (i.e., negative value represents deterioration of physical function).

Value in parentheses is 95% confidence interval.

Significant associations are shown in bold.

Abbreviations: VAS, visual analogue scale; PCS, physical component summary; SF-36, 36-Item Short Form Health Survey; Flex, flexion; Ext, extension; Abd, abduction; Add, adduction; ER, external rotation; IR, internal rotation.

* Adjusted for age, minimum JSW, comorbidity count, and physical function at baseline.

† Unit is 1,000 steps/day

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