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Original Research

The Impact of Spinopelvic and Hip Mobility on Passive Hip Flexion Range of Motion Assessment

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ABSTRACT

Background: Measuring passive hip flexion range of motion (ROM) is challenging due to compensatory movements. Despite the interest in using functional lateral radiographs for assessing hip mobility, the relationship with passive hip flexion ROM remains unclear. This study aims to elucidate this relationship and clarify spinopelvic parameters and mobility factors influencing variations in passive and radiographic hip flexion ROM.

Methods: A retrospective cross-sectional study was conducted on 154 preoperative patients undergoing primary total hip arthroplasty. Passive and radiographic hip flexion ROM were assessed to clarify these relationships, and these differences were classified into 3 groups (O, A and U). Spinopelvic and hip parameters were assessed in standing, relaxed-seated and flexed-seated positions, as well as lumbar, pelvis, and hip mobility between each position to identify factors influencing differences.

Results: There was a moderate correlation between passive and radiographic hip flexion ROM ($R^2 = 0.48$, $P < .01$). A significant difference was found in pelvic and hip alignment in the flexed-seated position between all groups. In postural changes, the O group, which had more patients with relatively low hip mobility, showed greater lumbar spine and pelvic movement, while the U group, which had more patients with relatively high hip mobility, showed less lumbar spine and pelvic movement.

Conclusions: This study confirmed that passive hip flexion ROM and radiographic hip flexion ROM correlate and that spinopelvic and hip alignment and mobility influence these differences. This result suggests that clinicians should consider lumbar and pelvic alignment and mobility in clinical practice to improve the accuracy of passive hip flexion ROM measurements.

Introduction

Hip range of motion (ROM) has conventionally been the main clinical outcome measure for diagnosing hip disorders such as osteoarthritis [1] and femoroacetabular impingement [2] and for evaluating the effectiveness of treatment such as total hip arthroplasty (THA) [3]. In clinical practice, passive hip ROM has long been measured using a goniometer, because of its ease of use and practicality, and its reliability has already been demonstrated [4]. In particular, it is important for clinicians to assess hip flexion ROM as it is related to level of hip pain, physical function, activities of daily living (ADLs) such as putting on and taking off socks and the risk of instability after THA [5-7]. Hence, passive hip flexion ROM assessment needs to be accurate [8]. However, it has been reported that measuring hip flexion ROM in the sagittal plane may be difficult [8]. This is because compensatory movements of lumbar flexion and posterior pelvic tilt can occur when measuring passive hip flexion ROM in the supine position [9]. A previous study has reported that pelvic rotation begins within the first 8° of passive and active hip flexion [10]. Another study described that measurement of hip ROM may not be accurate because spinal compensations often

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occur when measuring hip ROM [11]. Therefore, we consider that passive hip flexion ROM in the sagittal plane may be inaccurate.

In recent years, there has been increasing interest in assessing lumbar, pelvis, and hip alignment and mobility using functional lateral radiographs to assess the risk of dislocation for each patient before and after THA [12,13]. The advantages of using functional lateral radiographs are that compensatory movements of the lumbar spine and pelvis can be taken into account and that the exact femoral flexion angle relative to the pelvis can be measured. This means that hip flexion ROM itself can be easily and accurately assessed by radiological exam, but the problem is that radiological exam is invasive and may not be available in all clinical settings. Therefore, we consider that it is clinically useful to investigate the relationship between passive hip flexion ROM which is clinically easier and radiographic hip flexion ROM.

However, to our knowledge, the relationship between passive and radiographic hip flexion ROM, as well as the characteristics of spinopelvic parameters and mobility for these differences, have not been clarified. Therefore, the purpose of this study is to (1) clarify the relationship between passive and radiographic hip flexion ROM and (2) characterize spinopelvic and hip alignment and mobility for differences in passive and radiographic hip flexion ROM. Our hypothesis is that passive and radiographic hip flexion ROM are positively correlated. However, passive hip flexion ROM may be inaccurate for specific patients with spine or hip disease. In addition, clinicians may overestimate passive hip flexion ROM in the specific patients, and spinopelvic and hip alignment and mobility influence the difference between passive and radiographic hip flexion ROM.

Material and methods

Patients

This was a retrospective, cross-sectional study. This study was approved by the Institutional Review Board of the Kyoto City Hospital (authorization 803) and was conducted per the Helsinki Declaration of 2008. Patients with an indication for primary THA were included between July 2019 and December 2020 at Kyoto City Hospital (Japan). Exclusion criteria were absence of hip flexion ROM on physical examination ($n = 3$) and incomplete fill-in of the questionnaire ($n = 8$). Eventually, the remaining 154 patients were included in the analysis (Fig. 1), with 26 male (17%) and 128 female (83%), median age 70 [interquartile range: 63-76] years. The median body mass index (BMI) was 24 [Iinterquartile range: 21-26] (Table 1).

Passive hip flexion ROM

The degree of passive hip flexion ROM was measured by several examiners, with one of them performing a single assessment using a standard 2-arm goniometer in the supine position. The basic axis of the goniometer was defined as a line parallel to the horizontal line, and the axis of movement was defined as the femur. The physical therapist performed one measurement, taking care to keep the patient's trunk and opposite lower extremity as immobile as possible. The end of ROM was defined as the point at which the examiner feels a firm resistance or the patient's pain limits further movement [14]. ROM was rounded to the nearest 5°. The clinical experience of each examiner was assessed in years, as it could affect ROM. The preoperative measurements of passive hip flexion ROM were measured using the same protocol by well-trained examiners. All examiners have at least 5 years of experience, and the protocol was discussed beforehand with all of them. Passive hip flexion ROM was measured once, which limits the presentation of interobserver and intraobserver reliability. However, we addressed this limitation by assessing the reliability of passive hip flexion ROM in preoperative THA patients. The measurements were repeated in a blinded fashion, with 20% of the number of study subjects randomly selected. Interobserver and intraobserver reliability were assessed via the intraclass correlation coefficient and showed a substantial agreement of 0.71-0.94 (Supplementary Table 1).

Radiographic hip flexion ROM

A sagittal radiograph was acquired of each patient in flexed-seated position. The ROM of the femur was measured between the axis of the proximal femur and the sacral endplate. In order to compare this measurement to the passive assessment, a computed tomography scout view was also acquired in supine position, which is comfortable as in passive hip flexion ROM. The orientation of the sacral endplate relative to the horizontal line was measured in this view, and added to the previous radiological measurement of ROM, in order to obtain a radiological hip flexion ROM relative to the horizontal (Fig. 2). ROM was rounded to a 1° precision. Two experienced operators (1 hip surgeon [Y.K.] and 1 physical therapist [H.T.]) made the radiographic hip flexion ROM measurements. Measurements were repeated for 20% of all subjects, selected at random, in a blinded fashion. Interobserver and intraobserver reliability were assessed via the intraclass correlation coefficient and showed an excellent agreement of 0.94-0.96 (Supplementary Table 1). In addition, the radiographic hip flexion ROM minus passive hip flexion ROM (difference) was divided into 3 groups, given that the interquartile range of difference was $-10°$ to 13° and passive hip flexion ROM was measured in 5° increments: overestimate group (O group) with a difference of $-10°$ or less, appropriate group (A group) with a difference of $\pm 10°$, and underestimate group (U group) with a difference of $+10°$ or more.

Radiographic assessment

Functional lateral radiographs were obtained in free standing, relaxed-seated, and flexed-seated positions (Fig. 3). For the standing radiograph, the patients were advised to stand, look forward

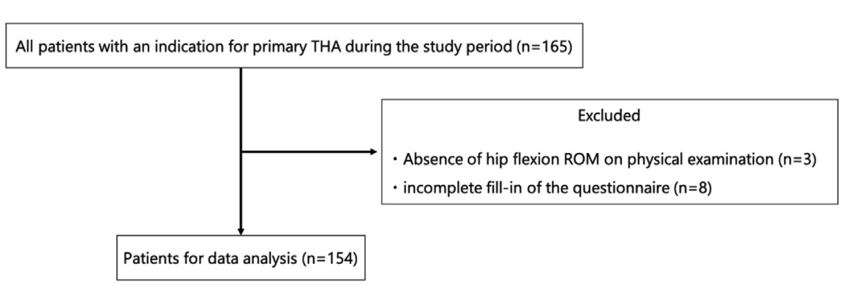

Figure 1. Flowchart of patients.

Table 1
Demographics of the included patients.

Variable	Whole (n = 154)	O Group (n = 38)	A group (n = 70)	U Group (n = 46)	*P* value
Age (y)	70 (63 to 76)	69 (60 to 73)	70 (63 to 75)	71 (64 to 80)	n.s.
Sex					n.s.
Female n (%)	128 (83%)	31 (82%)	54 (77%)	43 (93%)	
Male n (%)	26 (17%)	7 (18%)	16 (23%)	3 (7%)	
BMI (kg/m^2)	24 (21 to 26)	23 (20 to 25)	25 (21 to 26)	24 (21 to 25)	n.s.
Diagnosis of the operative side					n.s.
OA (%)	134 (87%)	32 (21%)	61 (40%)	41 (27%)	
ION (%)	9 (6%)	3 (2%)	4 (3%)	2 (1%)	
SIF (%)	4 (3%)	0 (0%)	3 (2%)	1 (1%)	
RDC (%)	7 (5%)	3 (2%)	2 (1%)	2 (1%)	
State of the contralateral side					n.s.
OA (%)	49 (32%)	13 (8%)	19 (12%)	17 (11%)	
THA (%)	27 (18%)	10 (7%)	9 (6%)	8 (5%)	
Normal (%)	78 (50%)	15 (10%)	42 (27%)	21 (14%)	
Tonnis grade (n = 134)					n.s.
0 (%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
1 (%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	
2 (%)	6 (5%)	1 (1%)	3 (2%)	2 (2%)	
3 (%)	128 (95%)	31 (23%)	59 (44%)	38 (28%)	
VAS (mm)	85 (75-95)	80 (70-95)	85 (70-95)	85 (80-98)	n.s.
JHEQ-pain (points)	6 (4-11)	7 (4-12)	7 (5-10)	5 (3-10)	n.s.
Years of rater's experience (y)	3 (2-10)	8 (2-11)	3 (2-8)	3 (2-10)	n.s.
Passive hip flexion ROM (°)	90 (75-95)	95 (86-110)	90 (76-95)	80 (70-90)	O vs A[b] O vs U[b] A vs U[a]
Radiographic hip flexion ROM (°)	90 (74-101)	76 (65-89)	89 (75-95)	103 (92-111)	O vs A[b] O vs U[b] A vs U[b]

The values are described as median, and the interquartile range are shown in parentheses.
ION, idiopathic osteonecrosis of the femoral head; n.s., not significant; OA, osteoarthritis; RDC, rapidly destructive coxarthropathy; SIF, subchondral insufficiency fracture; VAS, visual analog scale.
[a] $P < .05$.
[b] $P < .01$.

with fists overlaying ipsilateral clavicles [15]. The relaxed-seated position is defined as a 90∘ sitting position, with both femora parallel to the floor on a height-adjustable chair. Flexed-seated position is defined as a sitting position in which the femora are parallel to the floor with the trunk leaning maximally forward [12].

From these radiographs, spinopelvic and hip alignment parameters were measured, including pelvic incidence (PI), L1-S1 lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), pelvic-femoral angle (PFA). PFA was measured as the angle between the proximal femoral axis and the line connecting the center of the femoral heads and the midpoint of the sacral endplate [16,17] (Fig. 3). The radiological measurements were performed by an experienced researcher. The spinopelvic and hip mobility were calculated as the change from the standing position to a sitting position (either relaxed-seated or flexed-seated), which was indicated as $\Delta X_{standing/relaxed\text{-}seated\ or\ flexed\text{-}seated} = X_{relaxed\text{-}seated\ or\ flexed\text{-}seated} - X_{standing}$.

Lumbar mobility was defined as the difference in LL between the standing and sitting positions ($\Delta LL_{standing/relaxed\text{-}seated\ or\ flexed\text{-}seated}$). Pelvic mobility was defined as the difference in SS between the standing and sitting positions ($\Delta SS_{standing/relaxed\text{-}seated\ or\ flexed\text{-}seated}$). Hip mobility was defined as the difference in PFA between the standing and sitting positions ($\Delta PFA_{standing/relaxed\text{-}seated\ or\ flexed\text{-}seated}$). The interquartile range of differences in PFA from standing to flexed-seated was classified as low if less than 60°, moderate between 60° and 95°, and high above 95°. The hip user index is the contribution of the hip (ΔPFA) to the overall sagittal flexion (ΔPFA + ΔLL) during the transition from standing to flexed-seated positions [13]:

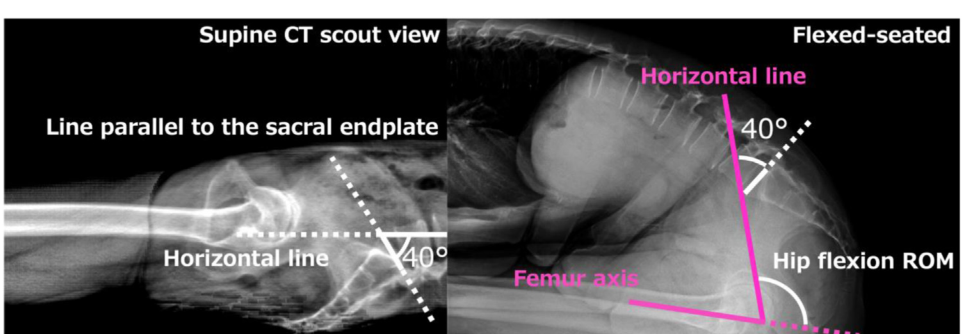

Figure 2. Assessment method for radiographic hip flexion ROM. ROM, range of motion.

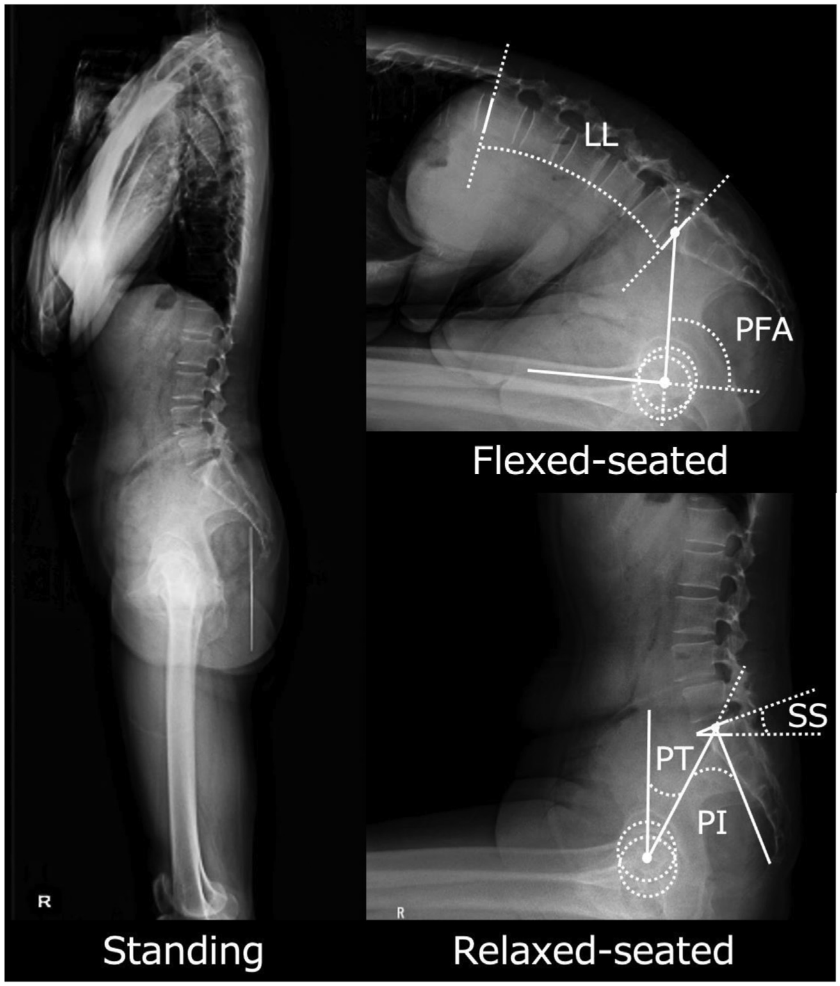

Figure 3. Diagram of radiographic measurement of spinopelvic parameters in functional lateral radiographs. Spinopelvic parameters are L1-S1 lumbar lordosis (LL), sacral slope (SS), pelvic tilt (PT), and pelvic-femoral angle (PFA).

$$\text{Hip user index} = \frac{\Delta \text{PFA}}{\Delta \text{PFA}+\Delta \text{LL}} \times 100\%$$

A high hip user index indicates that the hip joint significantly contributes to sagittal flexion, while a low hip user index indicates that sagittal flexion is primarily performed in the lumbar spine [18,19].

Pain

The intensity of hip pain at the time of radiographic evaluation was rated using a 100-mm horizontal visual analog scale, in which 0 mm represents no pain and 100 mm represents the worst pain. Also, the degree of hip pain was assessed using the Japanese Orthopaedic Association Hip Disease Evaluation Questionnaire (JHEQ), patient-reported outcome measures. The JHEQ is a self-administered questionnaire that consists of pain (28 points), movement (28 points), and mental (28 points) subscales, with higher scores indicating a better outcome. Each item is scored between 0 and 4 points, and the maximum total score is 84 points. The JHEQ has been shown to have higher validity and reliability compared to the 36-item Short Form Health Survey and the Oxford Hip Score [20,21]. Since pain was considered as covariate in this study, only JHEQ pain was used in the analysis.

Disease and severity

The type and severity of hip disease was assessed by one senior hip surgeon (Y.K). Types of disease on the operative side were classified as osteoarthritis of the hip joint, idiopathic osteonecrosis of the femoral head, rapidly destructive coxarthropathy, and subchondral insufficiency fracture. The contralateral hip was categorized as normal, osteoarthritis, or total hip arthroplasty. The severity of osteoarthritis was assessed using Tönnis grade. Tönnis grade is a general system for evaluating the severity of osteoarthritis on grades of 0 to 3, with higher grades indicating more severe osteoarthritis [22].

Statistical analysis

To determine the relationship between passive hip flexion ROM and radiographic hip flexion ROM, we used Spearman's rank correlation coefficient. Bland-Altman plots were used for ease of visualization of agreement between the 2 assessment methods [23]. The lower and upper limits of agreement were calculated as mean ±1.96 standard deviation [23]. After testing for normality using the Shapiro-Wilk test, Kruskal-Wallis test was used if any group was a non-normally distributed variable, and analysis of variance was used if any group was a normally distributed variable. If there was a significant difference, pairwise comparison was conducted using the Steel-Dwass test or the Tukey test. Chi-square test or Fisher's exact test was used for categorical variables. Significance level was set at $P < .05$, and data were reported as median [interquartile range]. Statistical analysis was performed using R4.1.2 (CRAN, freeware).

Results

Patient demographics are shown in Table 1. There were no significant differences in age, sex, and BMI between O, A, and U groups. Also, there were no significant differences in types of disease on the operative side, contralateral hip, and severity of osteoarthritis between O, A, and U groups. With regard to pain and years of clinical experience, no significant differences were found between O, A, and U groups.

Relationship between passive hip flexion ROM and radiographic hip flexion ROM

As initially hypothesized, a linear correlation was found between passive hip flexion ROM and radiographic hip flexion ROM ($R^2 = 0.48$, 95% confidence interval;0.35-0.59, $P < .01$) (Fig. 4), although differences between the 2 methods could be up to 30°. Furthermore, consistently with the initial hypothesis, passive hip flexion ROM was overestimated in some patients but also underestimated in others, which was contrary to our hypothesis (Fig. 4). The difference between the mean hip flexion ROM using the 2 methods was −1.08°, suggesting that there was little systematic error when hip flexion ROM was assessed using radiography (Fig. 5). The 95% limits of agreement ranged from −34° to 32°. This means that measuring passive hip flexion ROM can be in an error of up to approximately 30° compared to radiographic hip flexion ROM (Fig. 5).

Spinopelvic and hip alignment

There was no significant difference in spinopelvic and hip alignment in the standing position between all groups. However, in the relaxed-seated position, PT was significantly larger and PFA was significantly smaller in the O group compared to the U group (PT: 38° vs 29°; $P < .05$, PFA: 51° vs 60°; $P < .05$; Table 2). In the flexed-seated position, SS and PFA were significantly smaller and PT was significantly larger in the O group compared to the U group (SS: 29° vs 49°; $P < .01$, PFA: 66° vs 89°; $P < .01$, PT: 27° vs −2°; $P < .01$; Table 2).

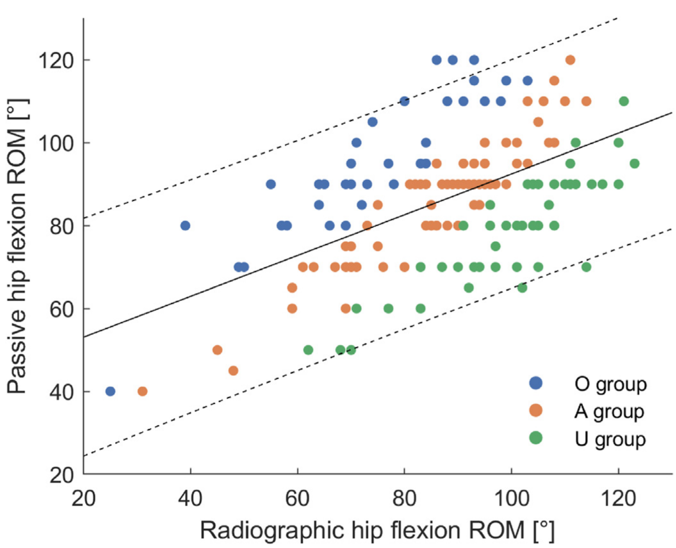

Figure 4. Relationship between passive hip flexion ROM and radiographic hip flexion ROM. The solid line represents the regression line ($R^2 = 0.48$, 95% confidence interval;0.35-0.59, $P < .01$), and the dashed line represents the 95% confidence interval of the prediction. ROM, range of motion.

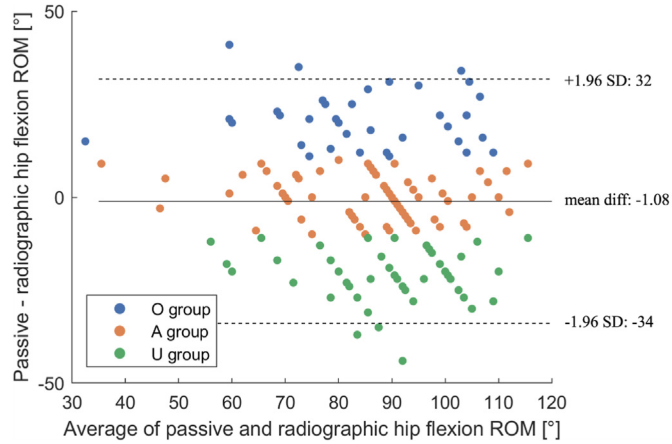

Figure 5. Bland-Altman plots for passive and radiographic agreement in hip flexion ROM. The solid line represents the mean difference between the 2 methods in hip flexion ROM, while the dashed line represents the lower and upper limits of LOA. LOA, limits of agreement; ROM, range of motion; SD, standard deviation.

Lumbar, pelvic, and hip mobility

In postural change from a standing to a relaxed-seated, ΔLL of the O group was predominantly larger movement than of the U groups (−23° vs −13°; $P < .05$; Table 3). Also, the ΔSS of the O group was significantly larger movement than that of the U groups (−20° vs −13°; $P < .05$; Table 3). In the postural change from standing to a flexed-seated, ΔSS of the O group was significantly lower movement than that of the A and U groups (−7° vs 5° vs 17°; $P < .05$ for O vs A, $P < .01$ for O vs U; Table 3). In addition, the ΔPFA for the U group was markedly larger movement than that for the O and A groups (66° vs 80° vs 94°; $P < .01$ for O vs U, $P < .01$ for A vs U; Table 3). Furthermore, the hip use index of the O group was dominantly low compared to that of the U group (60° vs 68°; $P < .01$; Table 3). Furthermore, there were relatively more patients with low hip mobility in the O group and, in contrast, relatively more patients with high hip mobility in the U group (Table 4).

Discussion

Passive hip flexion ROM has often been used as one of the clinical outcomes of THA [1], but more recently, functional lateral radiographs have been used to assess each patient's risk of dislocation, and radiological hip ROM is widely used [12,13]. However, the relationship between passive hip flexion ROM and radiographic hip flexion ROM, as well as the characteristics of the spinopelvic parameters and mobility that cause these differences, have not been clarified. This study is the first to clarify the relationship between passive hip flexion ROM and radiographic hip flexion ROM taking into account spinal and pelvic compensations. This study showed that the correlation was moderate, and that large differences were present, even though both methods were assessed. Two factors may have contributed to this result. The first is that compensatory movements of the lumbar spine and pelvis occurred during the measurement of passive hip flexion ROM, as suggested by previous studies [9,24]. The second is the difference in the degree of hip pain during hip flexion movements due to passive and active movements. In the O group, lumbar mobility was high, which contributed to overestimation. In fact, ΔLL was significantly greater in the O group and the lumbar spine was more flexible, which is consistent with this theory. On the other hand, radiographic hip flexion ROM was high in the U group, but passive hip flexion ROM was low. Although only the degree of hip pain at rest was assessed

Table 2
Spinopelvic and hip alignment for O, A, and U groups.

Variable	Whole (n = 154)	O group (n = 38)	A group (n = 70)	U group (n = 46)	*P* value
PI (Standing) (°)	52 (44 to 60)	54 (48 to 67)	53 (44 to 59)	49 (42 to 59)	n.s.
PI-LL (Standing) (°)	9 (−1 to 19)	10 (−1 to 24)	7 (0 to 17)	10 (−3 to 23)	n.s.
LL (°)					
Standing	46 (35 to 56)	47 (37 to 56)	47 (37 to 56)	45 (28 to 54)	n.s.
Relaxed-seated	24 (9 to 35)	19 (5 to 30)	26 (14 to 35)	25 (14 to 41)	n.s.
Flexed-seated	−3 (−9 to 17)	−5 (−14 to 2)	3 (−11 to 12)	−4 (−12 to 6)	n.s.
SS (°)					
Standing	38 (30 to 44)	42 (30 to 47)	38 (35 to 45)	36 (26 to 40)	n.s.
Relaxed-seated	18 (9 to 25)	15 (5 to 25)	18 (11 to 24)	21 (10 to 27)	n.s.
Flexed-seated	42 (30 to 52)	29 (16 to 42)	43 (31 to 51)	49 (40 to 60)	O vs A[a] O vs U[b] A vs U[a]
PT (°)					
Standing	17 (11 to 23)	19 (11 to 26)	16 (11 to 20)	19 (10 to 26)	n.s.
Relaxed-seated	35 (26 to 46)	38 (31 to 52)	35 (27 to 47)	29 (23 to 39)	O vs A n.s. O vs U[a] A vs U n.s.
Flexed-seated	12 (−2 to 27)	27 (12 to 40)	14 (0 to 26)	−2 (−7 to 11)	O vs A[b] O vs U[b] A vs U[b]
PFA (°)					
Standing	−6 (−14 to 2)	−8 (−16 to 2)	−6 (−10 to 2)	−6 (−14 to 2)	n.s.
Relaxed-seated	55 (44 to 65)	51 (39 to 62)	54 (42 to 63)	60 (49 to 68)	O vs A n.s. O vs U[a] A vs U n.s.
Flexed-seated	76 (60 to 89)	66 (48 to 74)	74 (59 to 87)	89 (79 to 96)	O vs A[a] O vs U[b] A vs U[b]

The values are described as median, and the interquartile range are shown in parentheses.
n.s., not significant.
[a] $P < .05$.
[b] $P < .01$.

in this study, it is possible that the radiographic hip flexion ROM is an active movement that allows the hip to flex slowly on its own, resulting in better hip flexion than the passive hip flexion ROM. We consider that these 2 factors resulted in a moderate correlation coefficient, although both methods assessed maximum hip flexion angle. A better understanding of these relationships may allow clinicians such as orthopedic surgeons and physical therapists to assess passive hip flexion ROM more accurately for appropriate targeted intervention, leading to improved patient ADLs and quality of life.

Spinopelvic and hip alignment and mobility play an important role in performing ADL, which may lead to quality of life . Vergari et al. [25] suggested that patients with low preoperative PT, T1PA, and PI-LL assessed for spinopelvic alignment, may show improved

Table 3
Spinopelvic and hip mobility for O, A, and U groups.

Variable	Whole (n = 154)	O group (n = 38)	A group (n = 70)	U group (n = 46)	*P* value
ΔLL (°)					
Standing/Relaxed-seated	−17 (−30 to −9)	−23 (−37 to −9)	−19 (−32 to −11)	−13 (−19 to −8)	O vs A n.s. O vs U[a] A vs U n.s.
Standing/ Flexed-seated	−46 (−56 to −34)	−51 (−66 to −39)	−44 (−55 to −36)	−45 (−53 to −32)	n.s.
ΔSS (°)					
Standing/Relaxed-seated	−16 (−25 to −10)	−20 (−32 to −10)	−17 (−26 to −11)	−13 (−19 to −7)	O vs A n.s. O vs U[a] A vs U[a]
Standing/Flexed-seated	7 (−7 to 18)	−7 (−20 to 11)	5 (−5 to 15)	17 (5 to 27)	O vs A[a] O vs U[b] A vs U[b]
ΔPFA (°)					
Standing/Relaxed-seated	59 (49 to 70)	56 (44 to 69)	58 (46 to 67)	65 (57 to 76)	n.s.
Standing/Flexed-seated	81 (62 to 96)	66 (58 to 85)	80 (63 to 90)	94 (79 to 104)	O vs A n.s. O vs U[b] A vs U[b]
Hip user index (%)	64 (55 to 72)	60 (48 to 64)	64 (55 to 72)	68 (62 to 75)	O vs A n.s. O vs U[b] A vs U n.s.

The values are described as median, and the interquartile range are shown in parentheses.
n.s., not significant.
[a] $P < .05$.
[b] $P < .01$.

Table 4
Hip mobility for low, moderate, and high groups.

Variable	Whole (n = 154)	Low group (n = 31)	Moderate group (n = 84)	High group (n = 39)	*P* value
O group (n = 38)		12 (32%)	21 (55%)	5 (13%)	
A group (n = 70)		14 (20%)	44 (63%)	12 (17%)	
U group (n = 46)		5 (11%)	19 (41%)	22 (48%)	
ΔLL (°)					
Standing/Relaxed-seated	−17 (−30 to −9)	−35 (−45 to −27)	−13 (−25 to −8)	−13 (−19 to −8)	L vs M[b] L vs H[b] M vs H n.s.
Standing/Flexed-seated	−46 (−56 to −34)	−54 (−63 to −40)	−42 (−54 to −32)	−47 (−55 to −32)	L vs M[a] L vs H n.s. M vs H n.s.
ΔSS (°)					
Standing/ Relaxed-seated	−16 (−25 to −10)	−36 (−46 to −25)	−16 (−23 to −11)	−10 (−15 to −5)	L vs M[b] L vs H[b] M vs H[b]
Standing/Flexed-seated	7 (−7 to 18)	−24 (−35 to −12)	6 (−2 to 14)	21 (16 to 28)	L vs M[b] L vs H[b] M vs H[b]
ΔPFA (°)					
Standing/Relaxed-seated	59 (49 to 70)	37 (27 to 48)	59 (53 to 68)	67 (57 to 75)	L vs M[b] L vs H[b] M vs H[b]
Standing/Flexed-seated	81 (62 to 96)	47 (41 to 54)	80 (73 to 86)	104 (100 to 109)	L vs M[b] L vs H[b] M vs H[b]
Hip user index (%)	64 (55 to 72)	49 (41 to 54)	64 (59 to 74)	69 (65 to 77)	L vs M[b] L vs H[b] M vs H[a]

The values are described as median, and the interquartile range are shown in parentheses.
n.s., not significant.
[a] $P < .05$.
[b] $P < .01$.

quality of life after THA. In addition, a previous study reported that most daily activities (eg, bending forward, standing to sitting, putting on socks) are accomplished by coordinated movements of the spine, pelvis, and hip [26]. Therefore, it is critically important for the clinician to assess spinopelvic and hip alignment and mobility in clinical practice. Interestingly, this study found no significant difference in spinopelvic and hip alignment in the standing position in any of the groups, but a significant difference was found with SS and PFA except for LL in the flexed-seated position in each of the groups. Our results showed that the O group had a relatively large number of patients with limited flexion, pelvis did not tilt forward, and the hip joints did not deeply flex. In contrast, the U group had relatively few patients with limited flexion, pelvis tilted forward and the hip joints deeply flexed. Flexed-seated position has been shown to be useful in assessing the risk of dislocation prior to THA surgery [19], and may also be useful in more accurately measuring the ROM of the hip joint itself in the flexion direction.

In terms of mobility, this study suggests that spinopelvic alignment and hip mobility influence the difference between passive and radiographic hip flexion ROM. During the postural change from standing to relaxed-seated, the pelvis tilts posteriorly an average of 15°-20°, and the acetabulum opens about 12°-16° to allow the femur, which can eventually flex 55°-70° [27,28]. In the case of the O group with low hip mobility, the amount of change to posterior pelvic tilt (ΔSS) and the amount of change to lumbar flexion to maintain sitting posture (ΔLL) were considered to be predominantly greater than in the U group with high hip mobility. In contrast, the amount of pelvic and lumbar spine change (ΔSS and ΔLL) was much less in the U group due to greater hip mobility. Similarly, during the postural change from standing to flexed-seated, the O group with low hip mobility had significantly less anterior pelvic change (ΔSS) and considerably less hip change (ΔPFA) than the U group with high hip mobility. These results support that the pelvis and lumbar spine change with hip flexion motion, and that the assessment of basic postural change (eg, standing-sitting) is crucial information for more accurate measurement of passive hip flexion ROM.

There are several limitations to this study. First, the average BMI of the subjects in the study was relatively low. In patients with a high BMI, passive hip flexion ROM measurement may be less accurate and radiographic assessment may be useful. Future studies should address the differences in accuracy between passive and radiographic hip flexion ROM according to the value of BMI. Second, the lumbar spine and pelvis may strictly move a little differently because the passive hip flexion ROM during measurement in the supine position was not evaluated radiographically. Future studies should examine whether lumbar spine and pelvic alignment in the supine position differs during passive hip flexion ROM measurement. While these limitations are present in this study, the strength of this study is that the first to show the relationship between clinical and radiographic hip flexion ROM and the influence of spinopelvic alignment and mobility on this difference.

Conclusions

This study confirmed that passive hip flexion ROM and radiographic hip flexion ROM correlate and that spinopelvic and hip alignment and mobility influence these differences. It is important for clinicians to assess lumbar spine and pelvic alignment and mobility during forward bending movements (eg, putting on socks) and common postural changes (eg, standing − sitting). In addition, the information obtained from this assessment may be useful determining passive hip flexion ROM more accurately, which can represent an additional evaluation method for clinicians to assess patients.

Conflicts of interest

The authors declare there are no conflicts of interest.

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CRediT authorship contribution statement

Hiroyuki Tokuyasu: Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation. **Eiki Tsushima:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis. **Mitsuru Takemoto:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Formal analysis, Conceptualization. **Claudio Vergari:** Writing – review & editing, Visualization, Validation, Project administration, Methodology, Formal analysis. **Hiroshi Tada:** Writing – review & editing, Supervision, Project administration. **Youngwoo Kim:** Writing – review & editing, Visualization, Validation, Supervision, Project administration, Formal analysis, Conceptualization.

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Supplementary Data

Supplementary Table 1
Reliability of measurements in passive and radiographic hip flexion ROM.

Reliability of Measurements	Intraobserver reliability		Interobserver reliability	
	ICC (1,1)	95% CI	ICC (2,1)	95% CI
Passive hip flexion ROM	0.94	0.90 to 0.97	0.71	0.51 to 0.84
Radiographic hip flexion ROM	0.96	0.96 to 0.99	0.94	0.85 to 0.97

CI, confidence interval; ICC, intraclass correlation coefficient.