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# The relationship between spino-pelvic-hip mobility and quality of life before and after total hip arthroplasty

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## Abstract

**Introduction** Total hip arthroplasty (THA) can significantly improve quality of life (QOL) in patients with hip osteoarthritis. A relationship exists between activity levels and postoperative QOL, but its determinants are not well known. The aim of this work was to investigate the relationship between hip, pelvis and lumbar spine mobility and alignment before and after THA with QOL.

**Material and methods** Consecutive patients with hip arthrosis and an indication for THA were included prospectively between July 2019 and December 2020, and they underwent lateral radiographs in free-standing, extension, relaxed- and flexed-seated position. Spinopelvic and hip parameters were measured, as well as their changes between positions to assess hip, pelvis and lumbar spine mobility. Patients were also administered QOL questionnaires. Data were collected preoperatively and 6 and 12 months postoperatively.

**Results** Seventy patients were included; QOL significantly increased 6 months after THA (from 18 [10; 27] to 61 [48; 72],  $p < 0.001$ ). QOL further increased by 10 points or more after 6 months in 18% of patients, while it decreased in 16%. The latter showed higher pelvic range of motion (between flexion and extension) than the former.

**Conclusions** This study confirmed that QOL is significantly improved by THA, and that spinopelvic alignment and function can play a role. Future work should elucidate how to better predict postoperative QOL from preoperative patient characteristics to improve patient treatment and establish early postoperative physical therapy for patients who could benefit from postoperative improvement of activity-related QOL.

**Keywords** THA · Surgery · Alignment · Mobility · QOL · JHEQ

## Introduction

Total hip arthroplasty (THA) can significantly reduce pain, improve hip function and, more in general, improve quality of life (QOL) of patients with hip osteoarthritis [1, 2]. Several studies demonstrated such improvement, especially in younger patients [1, 3], as well as the important relationship between QOL, health and hip function [4, 5]. For instance, Reine et al. [6] showed that preoperative activity level could have an impact on postoperative QOL, while Matsunaga-Myogi et al. [1] reported that activity level could increase up to 3 years postoperatively.

QOL in THA was also usually studied using Short Form 8, Short Form 36, the EuroQol (EQ-5D), or other similar questionnaires [1, 3, 4, 7], while hip function was quantified with tools such as the Harris hip score or the Oxford Hip Score.

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Nevertheless, the relationship between spinopelvic alignment and mobility, QOL and clinical outcome of THA is still poorly understood. For instance, results were contradictory on the association between QOL and hip function [8, 9]. This might be due to the fact that hip function scores are external measurements, and they do not take into account the subject's musculoskeletal conformation. Radiographic-based methods to evaluate spinopelvic mobility [10–12], which use sagittal radiographs in different positions (relaxed-seated, flexed-seated, free standing, extension) to measure the lumbar, pelvis and hip mobility, could allow estimating spinopelvic function more accurately, while relating it to pelvic incidence (PI).

Studying preoperative spinopelvic mobility and alignment could also help in predicting postoperative outcome. For instance, Innmann et al. showed that pelvic mobility had an impact on the hip disability and osteoarthritis outcome score one year postoperatively, Ochi et al. [13] reported that preoperative spinopelvic parameters were related to postoperative functional and gait scores, at least in the very short term (3 months).

The aim of this study was to analyze QOL before and after THA, under the hypothesis that radiological pelvic, hip and lumbar mobilities are related to QOL, both preoperatively and postoperatively, and that the analysis of balance and mobility could help to better understand and predict the clinical outcome.

## Materials and methods

### Patients

This is a prospective and consecutive cohort of patients. Seventy patients with hip arthrosis and with an indication for THA were included between July 2019 and December 2020 at Kyoto City Hospital (Japan). Exclusion criteria were: spinal implant with iliosacral screws, spinal fusion of more than two vertebral levels or scoliosis with coronal Cobb angle higher than 25°. Table 1 reports the demographical data of

the cohort. Institutional review board approved the data collection (authorization N. 621).

### Data collection and radiographic analysis

Full-body lateral radiographs were acquired in free standing position, in extension, and in a flexed-seated position (Fig. 1). For the extension radiograph, patients were asked to hold on to a horizontal bar slightly higher than shoulder level, and they were instructed to extend their pelvis and spine as much as possible. For the radiographs in flexed-seated position, patients were sitting on a stool, and they were instructed to bend forward as far as possible. Acquisitions were obtained preoperatively and six and twelve months after surgery. Status of the contralateral hip was noted (normal, osteoarthritis or THA).

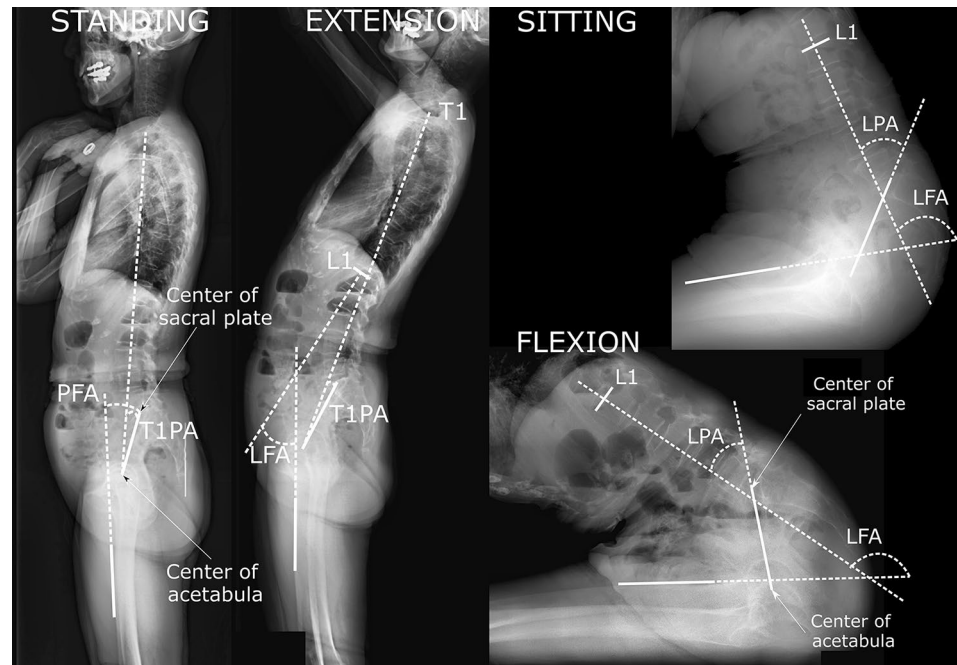
The following standard parameters were measured by an experienced operator in all radiographs: pelvic tilt (PT), pelvic incidence (PI), L1-S1 lumbar lordosis (LL), pelvic incidence minus lumbar lordosis (PI-LL), and T1-pelvic angle (T1PA, Fig. 1) [14]. In addition, the following parameters were computed: femoral sagittal tilt, as the angle between the vertical and a line along the frontal aspect of the first third of the femur diaphysis. The angle was considered positive in flexion and negative in extension [15]. Pelvic-femoral angle (PFA) was also measured, as the angle between the femur and a line drawn from the middle of the sacrum endplate to the centre of the interacetabular hip axis. Finally, lumbar-femoral angle (LFA) was measured as the angle between the femur and a line orthogonal to the L1 upper plateau (Fig. 1). LFA was positive in flexion and negative in extension, which is consistent with LFA being the sum of PFA and the lumbar-pelvic angle (LPA).

Pelvic mobility was considered as “stiff” if the difference between the relaxed-seated and standing SS was lower than 10°, normal between 10° and 30°, and hypermobile when higher than 30° [16]. Pelvic range of motion (ROM) was evaluated as the difference between SS in flexed-seated and extension. Lumbar mobility was considered as “stiff” if the change in LL between standing

**Table 1** Demographics of the cohort

	Preop	6 months postop	12 months postop
Number	70	62	57
Men/women	57/13	50/12	46/11
Age	66.0 [61.0; 72.0]	66.0 [61.0; 72.0]	65.1 [61.8; 71.7]
Body mass index	23.9 [21.9; 26.9]	23.9 [21.9; 26.5]	23.5 [21.7; 26.1]
Pelvic incidence [°]	46.6 [39.6; 54.2]	46.8 [39.4; 54.9]	46.9 [40.2; 54.4]
Stiff/normal/hypermobile hip (percentage)	17/69/14	3/85/12	0/85/15
Stiff/normal/hypermobile pelvis (percentage)	25/54/21	21/64/15	37/59/4
Stiff/normal/hypermobile lumbar spine (percentage)	5/29/66	4/25/71	12/43/45

**Fig. 1** Lateral radiographs in standing position, extension, relaxed seated and flexed seated. Main radiological parameters are reported: pelvic-femoral angle (PFA), T1-pelvic angle (T1PA), lumbar-pelvic angle (LPA), lumbar-femoral angle (LFA)



position and flexed-seated position was lower than  $20^\circ$ , “normal” for a change between  $20^\circ$  and  $40^\circ$ , and “hypermobile” for a change higher than  $40^\circ$  [12]. Hip mobility was defined as the difference in PFA between standing and flexed-seated positions. Hip was considered stiff for mobility  $< 40^\circ$ , normal between  $40^\circ$  and  $100^\circ$  and hypermobile above  $100^\circ$ .

### Quality of life assessment

Patients were administered the Japanese Orthopaedic Association Hip Disease Assessment Questionnaire (JHEQ)[17] preoperatively and at both postoperative stages. The JHEQ is a QOL assessment method that allows to quantify the patient’s QOL on a scale from 0 to 28 points (increasing with QOL) through 58 questions related to three categories: pain, activity and mental state. A total value can also be computed (with a maximum value of 84). The questionnaire contains general statements which are relevant for the whole population (“Event when I am at rest, my hip is painful”, or “It is difficult for me to climb up and down stairs”) but also a few questions addressing deep flexion and raising from the floor (“It is difficult for me to squat”), which are still relevant for the global population, but specifically targeting the Asian population [19].

Two groups of patients were formed according to their total QOL score change between 6 and 12 months: those that increased their score by more than 10 points and those that decreased by that same amount.

### Statistics

Preliminary statistical power analysis suggested that a cohort of 39 patients would allow to detect an improvement of 10 points in total QOL ( $\alpha=0.05$ ,  $\beta=0.95$ ). However, a larger cohort was included to improve the analysis of the correlations between QOL and sagittal alignment.

Differences between QOL parameters at different stages were analyzed with paired Friedman’s test for multiple comparisons. Correlations were quantified with multivariate regression analysis, to correct the confounding effect of age [18]. Stepwise correlation analysis was performed to build a multi-variable model to predict postoperative total QOL from preoperative analysis of sagittal balance.

Significance was set at  $p < 0.05$  and data were reported as median [quartiles]. Calculations were performed with Matlab 2021b (The Mathworks, Natick, USA).

### Results

Questionnaires 6 months postoperatively were only available for 62 patients, and 1-year postoperative questionnaires were available for 57 patients (Table 1). Contralateral hip was normal in twenty-nine patients, while twenty showed osteoarthritis and twenty-one had contralateral THA.

Table 2 reports all sagittal parameters measured at each stage and each position. Figure 2 shows QOL preoperative scores, compared to 6 months and 12 months postoperative ones. All QOL items significantly improved 6 months

**Table 2** Sagittal parameters measured at each stage (preoperative, 6 and 12 months postoperative) and in three positions: standing (Lat), extension (Ext) and flexed-seated (Flex)

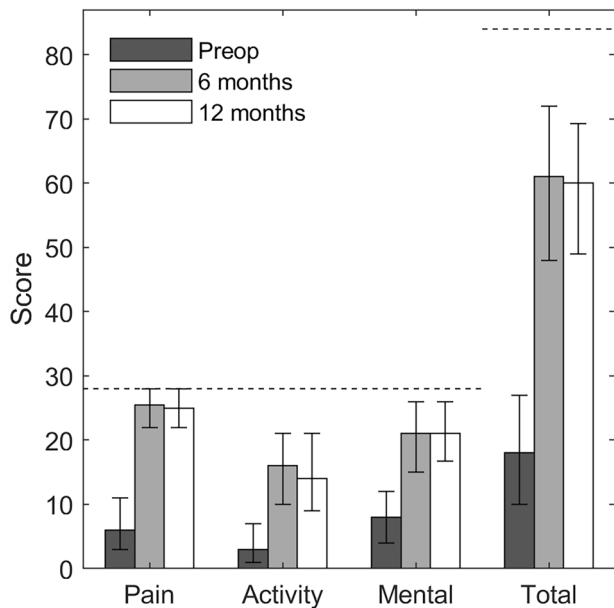
	Standing	Extension	Flexion	Differences
<b>T1PA [°]</b>				
Preop	14.0 [9.0; 23.1]	6.1 [-0.1; 12.9]	–	–
6 months	15.7 [9.2; 22.9]	6.7 [2.4; 13.1]	–	–
12 months	15.5 [11.5; 24.1]	8.4 [3.6; 15.3]	–	–
Differences by stage	–	–	–	–
<b>LL [°]</b>				
Preop	44.3 [33.1; 51.4]	48.6 [36.5; 57.9]	–8.2 [–14.6; 2.3]	Lat vs Flex**; Ext vs Flex**
6 months	45.0 [32.0; 54.6]	49.4 [39.1; 58.9]	–5.7 [–15.4; 2.2]	Lat vs Flex**; Ext vs Flex**
12 months	41.5 [30.6; 52.2]	46.7 [32.7; 55.5]	–2.0 [–10.2; 5.9]	Lat vs Flex**; Ext vs Flex**
Differences by stage	–	–	–	–
<b>SS [°]</b>				
Preop	34.4 [27.3; 42.0]	29.8 [21.6; 36.4]	37.2 [21.5; 50.7]	–
6 months	33.3 [27.7; 40.4]	27.7 [22.2; 36.5]	42.8 [29.5; 54.7]	Lat vs Flex*; Ext vs Flex**
12 months	33.9 [24.2; 41.2]	27.4 [18.5; 35.2]	48.3 [36.6; 56.4]	Lat vs Flex**; Ext vs Flex**
Preop	34.4 [27.3; 42.0]	29.8 [21.6; 36.4]	37.2 [21.5; 50.7]	–
<b>PT [°]</b>				
Preop	14.0 [7.9; 20.7]	18.1 [9.9; 23.9]	13.1 [0.1; 31.5]	–
6 months	14.7 [10.4; 21.9]	18.5 [13.2; 25.6]	8.8 [–3.6; 18.8]	Lat vs Flex*; Ext vs Flex**
12 months	16.5 [11.4; 21.9]	19.6 [14.3; 25.9]	0.9 [–5.7; 15.6]	Lat vs Flex**; Ext vs Flex**
Differences by stage	–	–	Preop vs 1 year*	–
<b>PI-LL [°]</b>				
Preop	7.9 [–1.4; 19.3]	0.6 [–8.7; 12.6]	57.7 [50.8; 66.6]	Lat vs Flex**; Ext vs Flex**
6 months	7.9 [–0.8; 18.3]	2.7 [–7.6; 11.2]	56.3 [49.1; 64.5]	Lat vs Flex**; Ext vs Flex**
12 months	9.3 [0.5; 20.8]	1.1 [–6.0; 15.0]	52.8 [46.4; 62.2]	Lat vs Ext*; Lat vs Flex**; Ext vs Flex**
Differences by stage	–	–	–	–
<b>Femoral tilt [°]</b>				
Preop	10.0 [7.4; 14.5]	9.1 [5.0; 15.3]	86.9 [82.7; 91.6]	Lat vs Flex**; Ext vs Flex**
6 months	9.9 [5.2; 13.3]	9.0 [5.4; 13.8]	86.9 [84.3; 90.3]	Lat vs Flex**; Ext vs Flex**
12 months	8.8 [5.5; 13.1]	8.9 [4.5; 13.5]	87.4 [83.9; 90.1]	Lat vs Flex**; Ext vs Flex**
Differences by stage	–	–	–	–
<b>PFA [°]</b>				
Preop	–3.2 [–13.6; 3.1]	–6.8 [–16.7; –1.2]	74.2 [55.1; 87.0]	Lat vs Flex **; Ext vs Flex **
6 months	–4.5 [–13.4; –0.5]	–8.1 [–16.6; –1.7]	80.8 [67.3; 91.5]	Lat vs Flex **; Ext vs Flex **
12 months	–5.5 [–13.1; –1.7]	–8.8 [–15.2; –5.4]	85.5 [74.6; 91.6]	Lat vs Flex **; Ext vs Flex **
Differences by stage	–	–	Preop vs 1 year *	–
<b>LFA [°]</b>				
Preop	3.0 [–4.6; 11.5]	–7.5 [–17.8; 3.4]	127.6 [115.8; 142.9]	Lat vs Ext **; Lat vs Flex **; Ext vs Flex **
6 months	1.2 [–7.7; 9.5]	–7.0 [–14.1; –1.7]	137.0 [122.5; 147.8]	Lat vs Ext **; Lat vs Flex **; Ext vs Flex **
12 months	0.5 [–5.3; 11.0]	–7.4 [–15.7; –1.2]	137.7 [130.4; 145.0]	Lat vs Ext **; Lat vs Flex **; Ext vs Flex **
Differences by stage	–	–	Preop vs 1 year *	–

\* $p < 0.05$ , \*\* $p < 0.001$

Parameters are: T1-pelvic angle (T1PA), L1-S1 lumbar lordosis (LL), pelvic tilt (PT), pelvic incidence (PI), pelvic incidence minus lumbar lordosis (PI-LL), pelvic-femoral angle (PFA), lumbar-femoral angle (LFA)

postoperatively ( $p < 0.0001$ ), and the total score improved in all patients (Fig. 3). Pain was resolved postoperatively for most patients (Fig. 2), while activity and mental status were improved, but they were still not optimal. However,

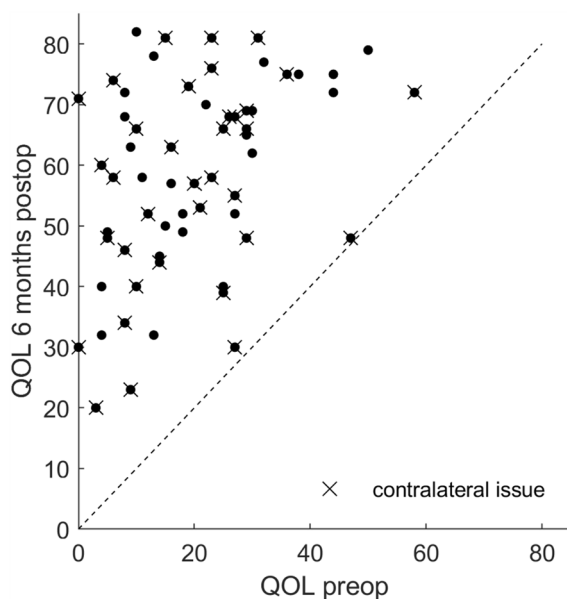
age had to be considered: the activity score was significantly higher in patients younger than 65 (20 [13; 23]) than in older patients (13 [6; 19],  $p = 0.006$ ). The total score was also slightly higher in younger patients (66 [50;



**Fig. 2** Quality-of-life items at three different stages. All quality-of-life items significantly increased six months postoperatively ( $p < 0.05$ ) and stabilized thereafter; the activity score decreased one year postoperatively, but not significantly. Horizontal dashed lines represent the maximum value for each item

75] vs 58 [45; 69],  $p = 0.08$ ), although the difference was not significant.

Overall, QOL remained constant between 6 and 12 months (Fig. 2,  $p > 0.05$ ). However, total QOL decreased by more than 10 points in 16% of patients

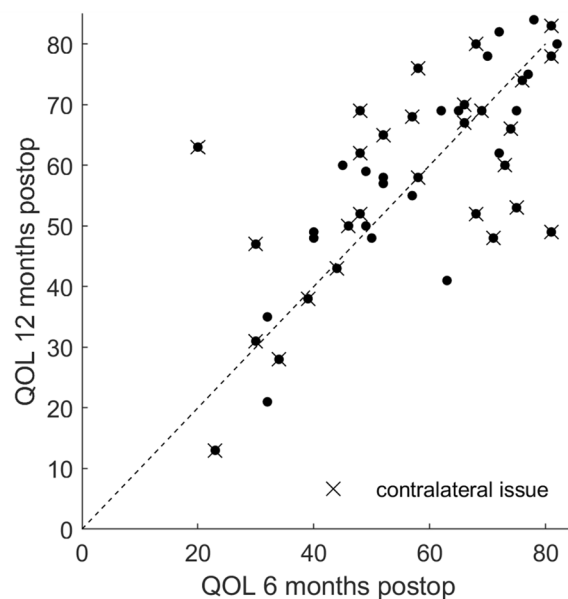


**Fig. 3** Quality-of-life total score (QOL) before and after surgery. Patients with contralateral osteoarthritis or total hip arthroplasty are highlighted as “contralateral issue” (x symbols). The points above

( $N = 8$ ) between 6 and 12 months, while it increased by more than 10 points in 18% ( $N = 9$ ). Patients for whom the QOL decreased in this period showed lower SS in extension at 6 months than those patients who increased their QOL ( $20.9 [16.9; 28.0]^\circ$  vs  $32.1 [26.0; 38.6]^\circ$ , respectively,  $p = 0.01$ ) and slightly higher SS in flexed-seated position ( $44.3^\circ [37.8; 50.0]^\circ$  vs  $35.6 [23.5; 51.4]^\circ$ ,  $p = 0.3$ ). Therefore, patients who decreased their QOL in the longer term showed higher postoperative pelvic range of motion ( $SS_{flexion} - SS_{extension} = 22.0^\circ [19.9; 24.8]^\circ$ ) than patients increasing their QOL ( $6.4^\circ [-5.9; 22.2]^\circ$ ). No differences were observed in the standing position. Lumbar and hip mobility was not associated to QOL postoperative changes ( $p > 0.05$ ) (Fig. 4).

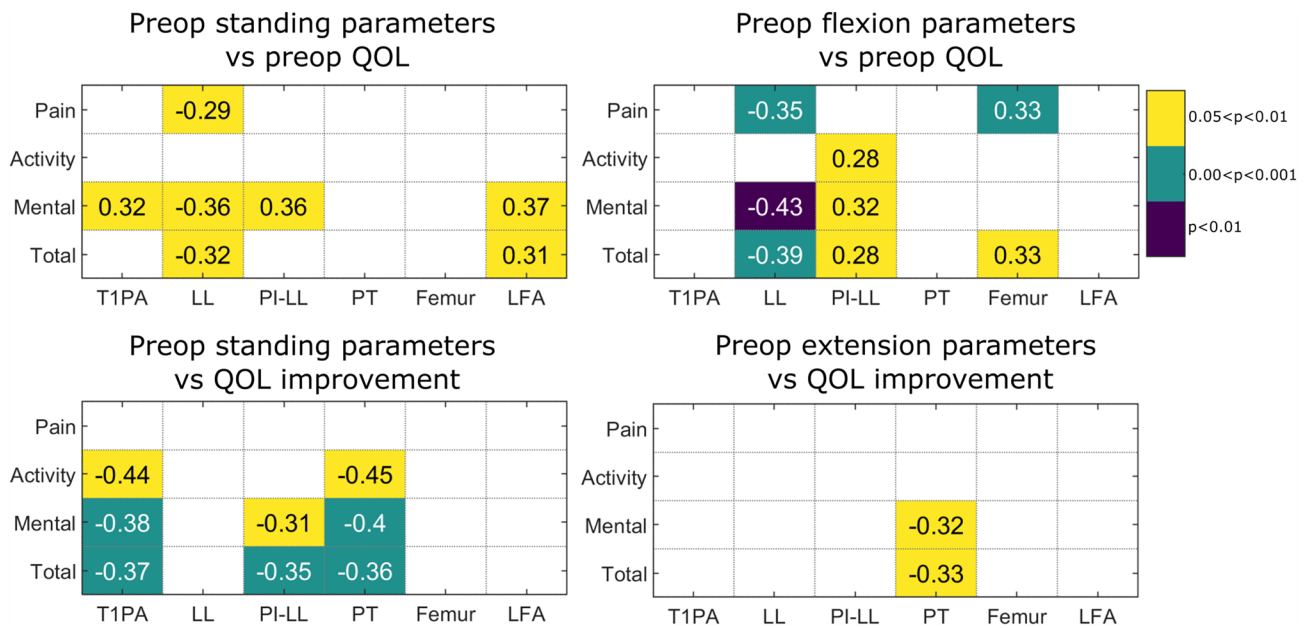
### Mobility

Pelvic, hip and lumbar mobilities had a minor impact on QOL (Fig. 5): 12 months postoperative, patients with postoperative hypermobile lumbar spine had significantly higher activity scores than normal ( $p = 0.02$ ) and stiff spines ( $p = 0.006$ ). Patients with postoperative stiff pelvis had significantly better pain scores 12 months postoperatively than normal pelvis mobility ( $p = 0.02$ ). A significant correlation was observed between preoperative PT and postoperative change of PT ( $R = -0.5$ ,  $p = 0.0001$ ), indicating that patients with low preoperative PT tended to increase their PT postoperative, and vice versa.



the bisector line improved their score; all postoperative scores were higher than the preoperative ones, however, QOL of 40% of patients decreased between 6 and 12 months postoperatively





**Fig. 4** Correlations between quality-of-life items (vertical axis) and geometrical parameters (horizontal axis. *T1PA* T1-pelvis angle; *LL* lumbar lordosis; *PT* pelvic tilt; *Femur* femoral tilt; *LFA* lumbar-femoral angle). *p*-values are represented as colours ( $p < 0.05$  in yellow and  $p < 0.01$  in green and  $p < 0.001$  in violet), while correlation coef-

ficients are reports as numbers. Quality of life (QOL) improvement was measured as the difference in score between six months postoperatively and preoperatively. Only parameters with significant correlations are represented

## Correlations

Figure 4 shows the correlations between sagittal alignment parameters and QOL scores. Age was significantly correlated with the postoperative improvement of the total QOL score ( $r = -0.28$ ,  $p = 0.08$ ) and with the activity score ( $R = -0.36$ ,  $p < 0.003$ ). Stepwise correlation analysis showed that preoperative pelvic tilt alone was the best predictor of postoperative total QOL and of QOL improvement (Fig. 6). However, root mean squared difference between predicted and actual QOL was 14.7.

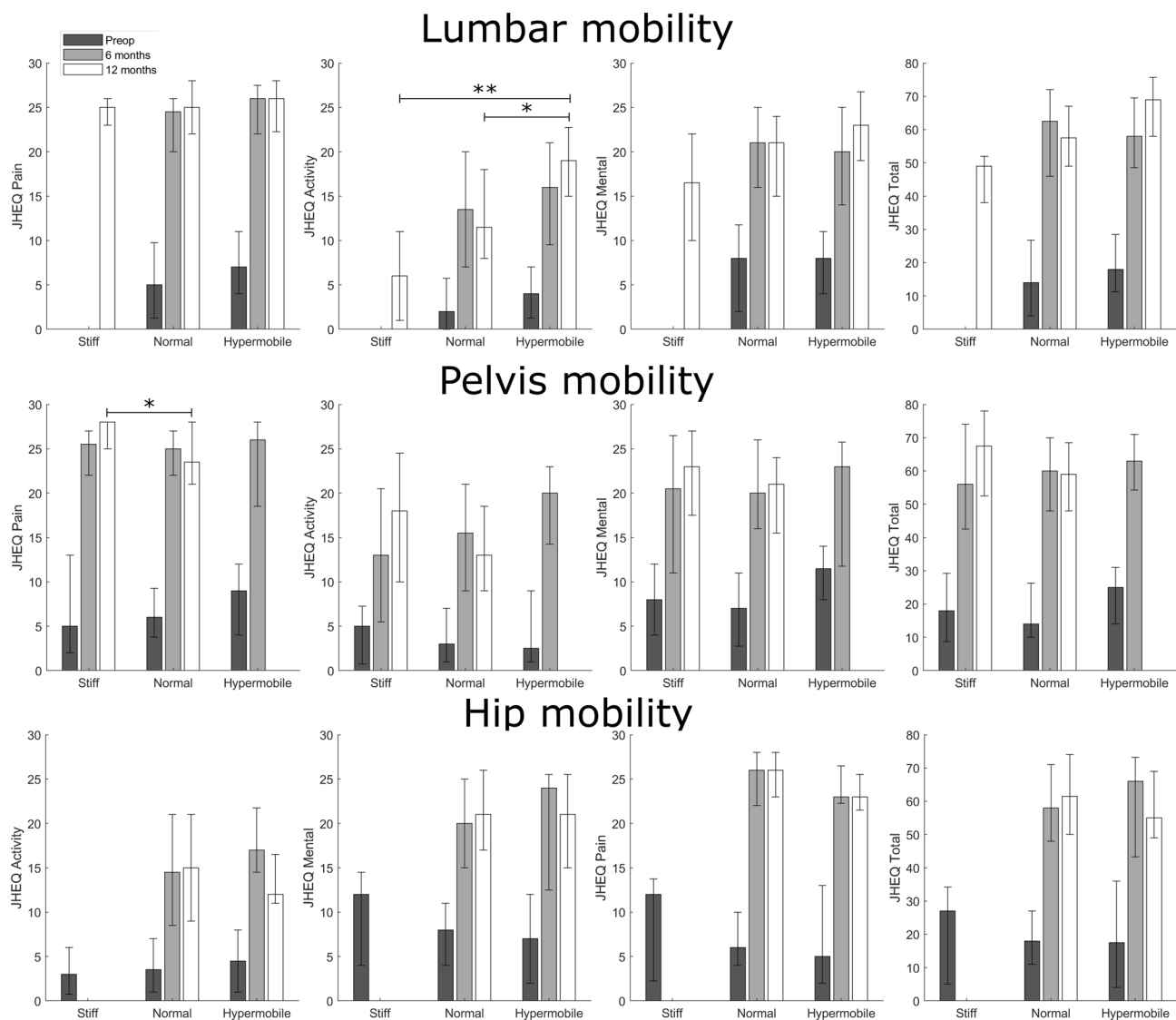
## Discussion

This study analyzed the relationships between QOL, sagittal balance and lumbar spine, hip and pelvis mobility. A previous study showed that QOL, which was quantified using a 8-item. Short Form Health Survey, did not vary between one and three years postoperatively [1]. However, another study by Costa et al. [3] suggested that QOL (measured with EQ-5D) could slightly decrease in the longer term of 5 years. In the present study, sagittal parameters did not significantly change between 6 months and 1 year, but significant differences were observed between preop and 1 year, especially in flexion. This further suggests that postoperative compensation mechanisms

continue after 6 months, in particular with an improvement of hip mobility. A possible interpretation is that patients tended to have stiff hip joint before surgery, and hence they had to use their lumbar and pelvic mobilities to compensate. Hip mobility was restored postoperatively, which resulted in a reduction of the number of patients with hypermobile pelvis and spine.

Analysis of correlations confirmed that QOL and sagittal alignment are related; interestingly, it is not the pain or activity scores that showed higher correlation with sagittal parameters, but rather the mental and total scores. Nevertheless, the correlations between the sagittal parameters in flexion and QOL scores confirm that lumbar spine and pelvis mobility plays a significant role in determining the dynamic and functional aspects of QOL. Furthermore, pelvis mobility seems to be relevant in the short-term evolution since patients who decreased their QOL by more than 10 points after 6 months postoperatively also had lower SS in extension and higher SS variation between flexion and extension.

Predicting postoperative QOL remains a challenge. A simple model consisting of preoperative PT is the best predictor of 6-months postoperative QOL and of QOL postoperative change. The prediction might not be sufficiently accurate to provide an expected outcome to the patient, but the uncertainty of the prediction (about 15 points) is similar to the inherent uncertainty of the JHEQ test (also 15 points, [20]). In general, patients can expect



**Fig. 5** Quality of life according to hip, pelvis and lumbar spine mobility. All differences between preop and post-op measurements were significant, and they were not represented in the figure to improve readability. Other significant differences were indicated (\*  $p < 0.05$ ; \*\*  $p < 0.01$ )

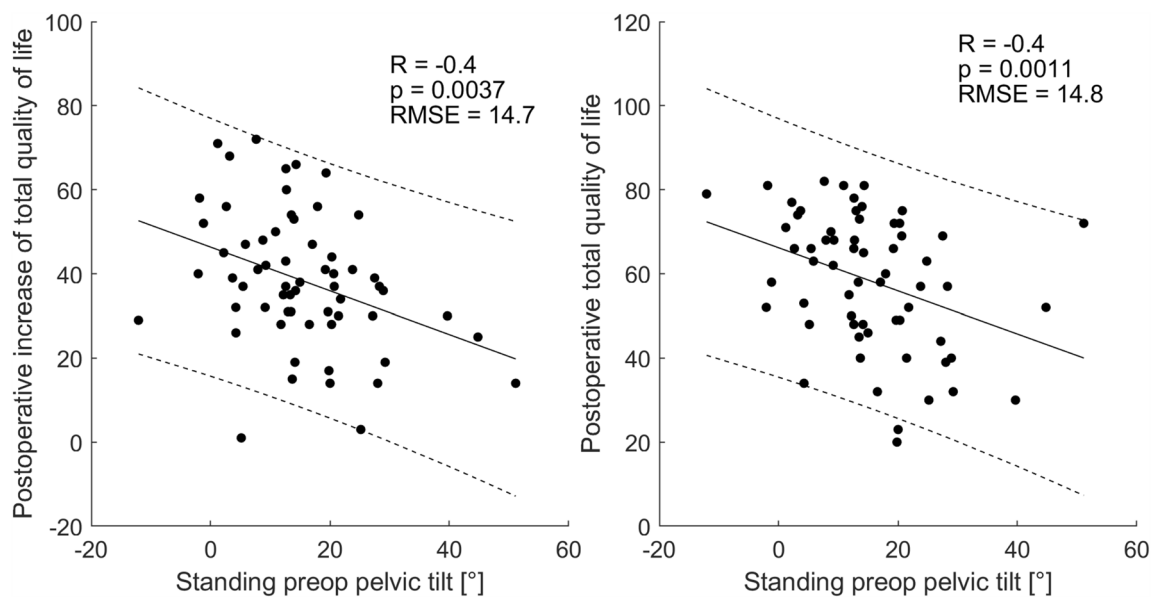
a better QOL improvement if they present low PT, T1PA and PI-LL angles, as well as low PT in extension.

This study presents some limitations. Firstly, postoperative QOL questionnaires were not available at both postoperative time points for all patients. Secondly, patient reported outcome questionnaire suffers from inherent low reproducibility: the bias of test–retest JHEQ questionnaire was previously estimated to be 1.5 points, with an uncertainty of about  $\pm 15$  points [20]. Nevertheless, clear trends were observed in the postoperative improvement of QOL, as well as in the relationship between QOL and radiological parameters. Finally, this study was conducted on a relatively small cohort, and it was monocentric, which could limit the generalizability of the results.

## Conclusion

This study confirmed that QOL and spinopelvic alignment and function are inter-related in THA. All patients improved their QOL after THA, but results suggest that patients with low preoperative PT, T1PA and PI-LL might benefit from an increased QOL improvement. Results also suggest that QOL can decrease between 6 and 12 months postoperatively in 16% of patients, while other patients continued improving in this time. Further studies could elucidate the functional determinants of this QOL deterioration, albeit small, in the medium to long term.





**Fig. 6** Correlation between preoperative pelvic tilt and 6 months postoperative total quality of life score and increase of total quality of life (postop–preop). Correlation was adjusted to remove the con-

founding effect of age, while sex and pelvic incidence did not affect this relationship. Dashed lines represent the 95% prediction interval

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**Authors contribution** CV: concept and design, obtaining of funding, analysis and interpretation of the data, drafting of the article, and final approval of the article. CV was the main investigator of this study, and performed all of the measurements. YK: provision of study patients, obtaining of funding, collection, analysis and interpretation of data, participation in the reproducibility study, critical revision of the article for important intellectual content and final approval of the article. MT: concept and design, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article. HT: measurements, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article. YS: provision of study patients, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article. CT: provision of study patients, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article. SF: provision of study patients, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article. SM: concept and design, obtaining of funding, analysis and interpretation of data, critical revision of the article for important intellectual content, and final approval of the article.

**Data availability** The data that support the findings of this study are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of interest** There are no conflicts of interest to declare.

**Research involving Human Participants** Institutional review board approved the data collection (authorization N. 621).

**Informed consent** Patients informed consent was collected.

**Consent to Publish** Not applicable.

## References

1. Matsunaga-Myoji Y, Fujita K, Makimoto K, Tabuchi Y, Mawatari M (2020) Three-year follow-up study of physical activity, physical function, and health-related quality of life after total hip arthroplasty. *J Arthroplasty* 35:198–203. <https://doi.org/10.1016/j.arth.2019.08.009>
2. Rissanen P, Aro S, Slätis P, Sintonen H, Paavolainen P (1995) Health and quality of life before and after hip or knee arthroplasty. *J Arthroplasty* 10:169–175. [https://doi.org/10.1016/S0883-5403\(05\)80123-8](https://doi.org/10.1016/S0883-5403(05)80123-8)
3. Costa ML, Achten J, Foguet P, Parsons NR (2018) Comparison of hip function and quality of life of total hip arthroplasty and resurfacing arthroplasty in the treatment of young patients with arthritis of the hip joint at 5 years. *BMJ Open* 8:e018849. <https://doi.org/10.1136/bmjopen-2017-018849>
4. Mariconda M, Galasso O, Costa GG, Recano P, Cerbasi S (2011) Quality of life and functionality after total hip arthroplasty: a long-term follow-up study. *BMC Musculoskelet Disord* 12:222. <https://doi.org/10.1186/1471-2474-12-222>
5. Quintana JM, Escobar A, Aguirre U, Lafuente I, Arenaza JC (2009) Predictors of health-related quality-of-life change after total hip arthroplasty. *Clin Orthop Relat Res* 467:2886. <https://doi.org/10.1007/s11999-009-0868-9>
6. Reine ST, Xi Y, Chhabra A, LaCross J, Kohli A, Wells JE (2022) Does preoperative activity level affect postoperative outcomes

- following total hip arthroplasty? *J Arthroplasty* 37:1314–1319. <https://doi.org/10.1016/j.arth.2022.03.009>
7. Harris WH (1969) Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty: an end-result study using a new method of result evaluation, *JBJS*, 51: 737–755.
  8. Davis KE, Ritter MA, Berend ME, Meding JB (2007) The importance of range of motion after total hip arthroplasty. *Clin Orthop Relat Res* 465: 180–184.
  9. Kawai T, Goto K, Kuroda Y, Okuzu Y, Matsuda S (2022) Discrepancy in the responsiveness to hip range of motion between harris and oxford hip scores. *Arthroplast Today* 13:157–164. <https://doi.org/10.1016/j.artd.2021.10.008>
  10. Vergari C, Kim Y, Takemoto M, Shimizu Y, Tanaka C, Fukae S et al (2022) Sagittal alignment in patients with flexion contracture of the hip before and after total hip arthroplasty. *Arch Orthop Trauma Surg*. <https://doi.org/10.1007/s00402-022-04606-y>
  11. Innmann MM, Reichel F, Schaper B, Merle C, Beaulé PE, Grammatopoulos G (2021) How does spinopelvic mobility and sagittal functional cup orientation affect patient-reported outcome 1 year after tha?—A prospective diagnostic cohort study. *J Arthroplasty* 36:2335–2342. <https://doi.org/10.1016/j.arth.2021.02.014>
  12. Kim Y, Vergari C, Shimizu Y, Tokuyasu H, Takemoto M. The Impact of Hip Mobility on Lumbar and Pelvic Mobility before and after Total Hip Arthroplasty. *J Clin Med* 2023; <https://doi.org/10.3390/jcm12010331>.
  13. Ochi H, Homma Y, Baba T, Nojiri H, Matsumoto M, Kaneko K (2017) Sagittal spinopelvic alignment predicts hip function after total hip arthroplasty. *Gait Posture* 52:293–300. <https://doi.org/10.1016/j.gaitpost.2016.12.010>
  14. Protopsaltis T, Schwab F, Bronsard N, Smith JS, Klineberg E, Mundis G et al (2014) The T1 pelvic angle, a novel radiographic measure of global sagittal deformity, accounts for both spinal inclination and pelvic tilt and correlates with health-related quality of life. *JBJS* 96:1631–1640
  15. Weng W-J, Wang W-J, Wu M-D, Xu Z-H, Xu L-L, Qiu Y (2015) Characteristics of sagittal spine–pelvis–leg alignment in patients with severe hip osteoarthritis. *Eur Spine J* 24:1228–1236. <https://doi.org/10.1007/s00586-014-3700-5>
  16. Ike H, Dorr LD, Trasolini N, Ste M, McKnight B, Heckmann N, et al. Spine-Pelvis-Hip Relationship in the Functioning of a Total Hip Replacement. *J Bone Joint Surg Am* <https://doi.org/10.2106/JBJS.17.00403>.
  17. Matsumoto T, Kaneuji A, Hiejima Y, Sugiyama H, Akiyama H, Atsumi T, et al. Japanese Orthopaedic Association Hip Disease Evaluation Questionnaire (JHEQ): a patient-based evaluation tool for hip-joint disease. The Subcommittee on Hip Disease Evaluation of the Clinical Outcome Committee of the Japanese Orthopaedic Association. *J Orthop Sci* 2012;17:25–38. <https://doi.org/10.1007/s00776-011-0166-8>.
  18. Yan H, Karmur BS, Kulkarni AV (2020) Comparing effects of treatment: controlling for confounding. *Clin Neurosurg* 86:325–331. <https://doi.org/10.1093/neuros/nyz509>
  19. Fujita K, Kang HS, Mawatari M, Makimoto K, Lee M, Hwang J (2018) Quality of life, effects on Asian Lifestyle, and perceived satisfaction after total hip arthroplasty in Japan and Korea. *Int J Orthop Trauma Nurs* 31:20–25. <https://doi.org/10.1016/j.ijotn.2018.07.001>
  20. Watanabe N, Murakami S, Uchida S, Tateishi S, Ohara H, Yamamoto Y et al (2020) Validity of the Japanese orthopaedic association hip disease evaluation questionnaire (JHEQ) for Japanese patients with labral tear. *J Hip Preserv Surg* 7:466–473. <https://doi.org/10.1093/jhps/hnaa038>

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