Optimal Retractor Insertion Point for Nerve Safety During Total Hip Arthroplasty: An Anatomical Study on the Femoral and Sciatic Nerves in Relation to Hip Motion

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Abstract:	ABSTRACT Background Nerve injury is one of the most serious complications of total hip arthroplasty (THA). It is suspected to be result from nerve compression or direct injury caused by an acetabular retractor. The anatomical relationship between the acetabular rim and the femoral and sciatic nerves, including hip motion, has not been investigated. This study aimed to identify the optimal position for retractor insertion during THA to prevent nerve damage. Methods A total of 28 hip joints from 14 freshly frozen cadavers were used. Using an anterolateral approach, each cadaver was immobilised in the lateral decubitus position and deployed to measure the distance between the nerves and the acetabular rim, while the hip joint was changed to the extension, neutral, and flexion positions. Results Three femoral nerve was closest to the anterior margin of the acetabulum at 90° and 120° of extension and farthest away at 30° of flexion. The sciatic nerve was closest to the posterior margin of the acetabulum at 90° and 120° of flexion and farthest away at 30° and 150° of extension compared with the other points. Conclusion To prevent nerve damage during THA, we suggest that the retractor be inserted at the points where the nerves are the farthest away, such as at 30° and 150°. The femoral and sciatic nerves vary in their movements depending on the hip position. Therefore, the safe insertion of a retractor is recommended for hip flexion of the femoral nerve and extension of the sciatic nerve. Additionally, it is important to carefully insert the retractor

	along the acetabular margin without penetrating the joint capsule. Overall, this study provides valuable insights into the anatomical location and movement of the femoral and sciatic nerves in relation to hip motion and can help inform surgical techniques for safer THA.

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ABSTRACT

Background

Nerve injury is one of the most serious complications of total hip arthroplasty (THA). It is suspected to be result from nerve compression or direct injury caused by an acetabular retractor. The anatomical relationship between the acetabular rim and the femoral and sciatic nerves, including hip motion, has not been investigated. This study aimed to identify the optimal position for retractor insertion during THA to prevent nerve damage.

Methods

A total of 28 hip joints from 14 freshly frozen cadavers were used. Using an anterolateral approach, each cadaver was immobilised in the lateral decubitus position and deployed to measure the distance between the nerves and the acetabular rim, while the hip joint was changed to the extension, neutral, and flexion positions.

Results

Three femoral nerve was closest to the anterior margin of the acetabulum at 90° and 120° of extension and farthest away at 30° of flexion. The sciatic nerve was closest to the posterior margin of the acetabulum at 90° and 120° of flexion and farthest away at 30° and 150° of extension compared with the other points.

Conclusion

To prevent nerve damage during THA, we suggest that the retractor be inserted at the points where the nerves are the farthest away, such as at 30° and 150°. The femoral and sciatic nerves vary in their movements depending on the hip position. Therefore, the safe insertion of a retractor is recommended for hip flexion of the femoral nerve and extension of the sciatic nerve. Additionally, it is important to carefully insert the retractor along the acetabular margin without penetrating the joint capsule. Overall, this study provides valuable insights into the anatomical location and movement of the femoral and sciatic nerves in relation to hip motion and can help inform surgical techniques for safer THA.

Keywords: total hip arthroplasty, nerve injury, retractor insertion, hip motion, optimization

INTRODUCTION

Nerve injury is one of the most serious complications after total hip arthroplasty (THA), with an incidence rate of 0.6-3.7% [1-3]. Of these, sciatic nerve palsy is the most encountered nerve injury associated with THA, with an incidence of 0.17-1.5% [4-6]. Femoral nerve palsy is the second most common nerve injury, with a reported incidence of 0.01-0.55% [4, 7, 8].

The cause of postoperative nerve palsy is not fully understood, but it is often due to compression of the nerve by the retractor [9] or direct injury to the nerve by the tip of the retractor [10]. In particular, the insertion of a retractor into the anterior wall of the acetabulum during THA via the anterolateral approach has been shown to be associated with an elevated risk of femoral nerve injury [11, 12]. Similarly, we

considered that deep insertion of a retractor into the posterior wall of the acetabulum may injure the sciatic nerve (Fig. 1). Relationships between the femoral nerve and the acetabular rim have been reported via the direct anterior approach, with the patient in a supine position [11, 12]. However, the relationship between the femoral nerve and the acetabular rim, as well as that between the sciatic nerve and the acetabular rim using an anterolateral approach in the lateral decubitus position, has not yet been reported. Furthermore, to the best of our knowledge, no studies have reported that the distance between the anterior acetabular rim and femoral nerve changes in response to hip joint movement.

This cadaveric study aimed to clarify the anatomical features of the femoral and sciatic nerves around the acetabular rim and to investigate the changing distance between the anterior acetabulum rim and femoral nerve, as well as that between the posterior acetabulum rim and the sciatic nerve according to hip joint motion. Finally, the optimal position for retractor insertion during THA using the anterolateral approach was determined in the lateral supine position.

METHODS

A total of 14 freshly frozen human cadavers (7 males and 7 females, mean age of 71.2 [range, 42-92] years), provided by the Department of Anatomy, Chiang Mai University, were included in this study. Specimens were prepared by thawing overnight at room temperature on the day before the experiment and then sectioned over the first lumbar vertebra. The specimen was positioned on the operating table in the lateral decubitus position, with the affected side up. Each specimen underwent an anterolateral-approach based-THA (modified Watson-Jones approach) [Orthopädische Chirurgie München (OCM) approach] [13]. The acetabulum was exposed after the femoral head and neck were removed using standard procedures.

Measurement of the distance between the femoral and sciatic nerves and the acetabulum

A reference line was drawn through the centre of the acetabulum and that of the transverse ligament following the method of Dikici et al. [14]. The point of intersection of this line with the superior and inferior margins of the acetabulum was set at 0° and 180°, respectively. Ten measurement points were established: 5 at every 30° anterior margin of the acetabulum and 5 at every 30° posterior margin of the acetabulum (Fig. 2). The distance between the femoral nerve and acetabulum was measured from the shortest distance from 5 measuring points every 30° along the anterior acetabular rim from 30° to 150°. Similarly, the distance between the sciatic nerve and acetabulum was measured at 5 measurement points along the posterior acetabular rim every 30° from 30° to 150°. The minimum distance from each point to the femoral and sciatic nerves was measured using a depth gauge with the hip in 0° flexion, 0° abduction, and neutral rotation.

Measurement of the distance in response to hip motion

The neutral position was defined as when the hip joint was in 0° flexion, 0° abduction, or 0°

internal/external rotation. The position wherein the hip joint is in 30° flexion, 0° abduction, and 0° internal/external rotation was defined as the flexion position, while that wherein the hip joint is in 30° extension, 0° abduction, and 0° internal/external rotation was defined as the extension position. The shortest distance from each point to the femoral and sciatic nerves was measured using a depth gauge in the extension, neutral, and flexion positions of the hip joint. Two surgeons performed all procedures and measurements.

The sample sizes required to assess intra- and inter-examiner reliabilities were 8 and 11, respectively, according to reliability study estimates using the intraclass correlation coefficient (ICC) [15]. Using the above sample sizes as a reference, the first 14 hips were measured twice with the timing staggered by one surgeon, and the remaining 14 hips were measured by 2 surgeons to assess intra- and inter-examiner reliability.

Statistical Analysis

The results were evaluated using descriptive statistics such as means and standard deviations. The distance between each nerve and the acetabular rim was confirmed to follow a normal distribution using the Shapiro-Wilk test. Comparisons between each measurement point at the hip joint in extension, neutral, and flexion positions were made using one-way analysis of variance (ANOVA), and post-hoc tests were performed using the Tukey–Kramer method. In addition, comparisons between these positions at each measurement point were made using repeated-measures ANOVA with the Tukey-Kramer method. The ICC was used to assess intra- and inter-observer reliability. Statistical analyses were performed using SPSS for Mac OS version 28.0 (IBM Corp., Armonk, NY, USA).

RESULTS

The femoral nerve was significantly closer to the anterior acetabular rim at the 90° and 120° points in neutral position than at the other measurement points, with an average distance of 21.1 ± 7.4 mm and 22.1 ± 6.8 mm, respectively (Fig. 3). The distance from the points at angles of 90° and 120° did not differ significantly (Table 1). In contrast, the 30° point was found to be the farthest away, with an average of 33.7 ± 9.2 mm. When the limb position was varied, the femoral nerve was significantly closer to the anterior rim at the 90° and 120° points in extension, with mean distances of 17.3 ± 6.2 mm and 18.0 ± 6.5 mm, respectively. In addition, there was no significant difference between angles of 90° and 120°. In the flexed position, the average distance was 35.1 ± 8.5 mm at 30°, which was significantly further from the anterior rim. Upon comparing the extension and flexion positions, all measurement points from 30° to 150° showed significant proximity to the anterior edge in extension and a significant distance from the anterior edge in flexion (Table 2).

The sciatic nerve was closest to the posterior acetabular rim at the 90° point in the neutral position, as compared to the other measurement points, with an average distance of 24.3 ± 7.2 mm. In contrast, the 30° and 150° points were significantly farther away, with average distances of 37.4 ± 9.1 mm and 35.9 ± 10.0 mm, respectively (Fig. 4). The distance from the points at angles of 30° and 150° did not differ significantly (Table 1). When the limb position was varied, the sciatic nerve was significantly closer to the posterior rim in the flexed position than in the other positions, with an average distance of 21.0 ± 6.7 mm and 23.9 ± 8.4 mm at the 90° and 120° points, respectively. In extension, the sciatic nerve was significantly further away at the 30° and 150° points, with average distances of 39.7 ± 7.9 mm and 39.6 ± 9.8 mm, respectively. All measurement points from 30° to 150° showed that the sciatic nerve was significantly closer to the posterior edge of the labrum in the flexion position and significantly farther away in the extension position (Table 2).

In summary, the anterior acetabulum was the farthest from the femoral nerve at 30° of hip flexion, and the posterior acetabulum was the farthest from the sciatic nerve at 30° and 150° of hip extension.

The ICCs for the inter-observer reliability of the distance measurement were 0.983 (0.978-0.987) and 0.988 (0.984-0.991) for the femoral nerve and sciatic nerve, respectively. The ICCs for the intra-observer reliability of the distance measurement were 0.989 (0.986-0.992) and 0.99 (0.987-0.991) for the femoral nerve and sciatic nerve, respectively. The values were all deemed very good.

DISCUSSION

It is necessary to insert the retractor correctly and safely around the acetabulum for proper exposure during THA. However, incorrect retractor positioning is a leading cause of intraoperative nerve injury during THA [16]. The femoral and sciatic nerves are commonly at risk of injury, and the safe placement of the retractor needs to be verified. Yoshino et al. [12] reported that the distance between the femoral nerve and anterior acetabulum may correlate with the risk of nerve injury. Therefore, surgeons performing THA should be aware of the distance between the acetabulum and the nerve.

Distance between the femoral nerve and the anterior acetabular rim

Several previous studies have examined the distance from the femoral nerve to the anterior acetabulum in normal hips, using computed tomography (CT), magnetic resonance imaging (MRI), or cadavers. At the 3 or 9 o 'clock position, an almost similar level as the point of 90°, the mean distance to the femoral nerve ranged from 18.0 mm to 23.6 mm [10] [12, 17-19]. In the present study, the mean distance to the femoral nerve from the 90° point of the anterior acetabulum was 21.1 ± 7.4 mm. This result is consistent with data from previous studies. Shubert et al. [17] also measured the distance from the anterior acetabular retractor position to the femoral neurovascular structure on CT scans and cadavers in a supine position and reported that the anterior inferior iliac spine (AIIS) was the most distant position, with a mean of 26.5 mm and 28.1

mm, respectively. In the present study, the position of the AIIS, at an angle of 30°, was also at the furthest position, with an average of 33.7 ± 9.2 mm. In addition, the 150° position was also significantly farther away than the 90° and 120° positions, with an average of 26.6 ± 7.3 mm. Therefore, a 30° position is recommended, while the 150° position is considered to be relatively safe, although inferior to the 30° position when inserting a retractor into the anterior acetabulum with the hip in a neutral position. Based on the results of this study, the hip flexion position is recommended for the insertion of an anterior retractor because the distance to the femoral nerve is significantly greater in the flexion position at an angle of 60°-150° than in the neutral position. Conversely, the insertion of a retractor in the extension position should be avoided because the distance to the femoral nerve is closer in all positions of extension than in the neutral position. This is a new recommendation, as no previous reports have been found on the changing distance between the femoral nerve and anterior acetabular rim as because of changes in the hip position.

Distance between the sciatic nerve and posterior acetabular rim

Shubert et al. [17] measured the distance from the posterior retractor position to the sciatic nerve on CT tomography and reported an average of 17.5 mm. Wang et al. [18] measured the distance from the 90° position to the sciatic nerve using MRI and reported an average of 19.4 mm. In a cadaveric study, Dikici et al. [14] exposed the sciatic nerve using the posterior approach in the prone position, removed the pisiform, adductor, superior, inferior, and posterior glenoid muscles, and measured the distance between the acetabulum and the sciatic nerve. They reported that an average distance of 21.0 mm at the 90° position in this study. In the present study, the average distance was 24.3 ± 7.2 mm at the 90° position, which is generally in agreement with previous reports. Furthermore, Dikici et al. [14] reported that the distance from the superior acetabular rim, an almost similar level as the point of 30°, to the sciatic nerve was the furthest, with a mean of 25.7 mm. We also found this position to be the furthest with an average of 37.4 ± 9.1 mm. However, we speculate that the difference of approximately 12 mm between our results and those of Dikici et al. may be because they conducted their study in the prone position, whereas the present study was conducted in the lateral decubitus position. In addition, at 150°, the results of the present study were significantly more distant than those in the other positions, with an average of 35.9 ± 10.0 mm. Therefore, points at 30° and 150° are recommended when inserting a retractor into the posterior acetabulum in a neutral position.

The findings of this study showed that the sciatic nerve is also affected by hip position. Therefore, hip flexion should be avoided, and extension is recommended as a safe position for retractor insertion. Furthermore, we consider the posterior acetabular capsule to be an important tissue when inserting a retractor into the posterior rim of the acetabulum, as it plays a protective role for the sciatic nerve. Similarly, we believe that the anterior acetabular capsule is important for preventing the retractor from being inserted too deeply and should be preserved as much as possible.

Although our study may guide the insertion of acetabular retractors in THA, it had several limitations. First, this study measured the distance between the acetabulum and femoral and sciatic nerves in the normal hip joint. In patients with hip osteoarthritis, morphological deformities and osteophytes may influence distance. Second, the differences in the measurements were in the range of a few millimetres, which is a small difference. However, this difference in measurements may be clinically important, as a difference of only a few millimetres can cause nerve damage. Third, we removed some structures to expose the anatomy of the femoral and sciatic nerves after using a real surgical approach. Although these methods were unavoidable, they may have altered the normal anatomical position of the nerves. However, because the results were generally consistent with those obtained using CT and MRI, we considered the present results valid.

In conclusion, the femoral nerve is closest to the anterior acetabular rim at 90° and 120°; therefore, when inserting a retractor during THA surgery, the 90° and 120° points should be avoided and the 30° or 150° points should be selected as much as possible. The femoral nerve also changes with the hip joint position. Therefore, it is safer to insert the retractor with the hips in flexion. The distance between the sciatic nerve and acetabulum was the closest at 90°. Therefore, the retractor should be inserted at 30° and 150° to avoid the 90° point. The sciatic nerve also changes its movement depending on the hip position; therefore, it is safer to insert the retractor posteriorly with the hip in extension.

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Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

Research Ethics and Informed Consent

We obtained ethics approval from the Research Ethics Committee of Chiang Mai University (STUDY CODE: ANA-2565-09180). The cadavers of this study were provided by the Department of Anatomy, Chiang Mai University. Written informed consent to use the cadavers was obtained from the patient before death. All the procedures were conducted in accordance with the relevant guidelines.

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Table 1. *P*-values for pairwise comparison between the distances from each measurement point to the nerves for extension, neutral, and flexion.

Comparisons between each measurement point		60°			90°			120°			150°		
		Extension	Neutral	Flexion	Extension	Neutral	Flexion	Extension	Neutral	Flexion	Extension	Neutral	Flexion
Femoral nerve	30°	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**
	60°	-	-	-	<.001**	0.003*	0.031*	<.001**	0.022*	0.131	0.544	1	0.999
	90°				-	-	-	0.98	0.941	0.974	0.002*	0.001*	0.009*
	120°							-	-	-	0.015*	0.009*	0.053
	150°										-	-	-
Sciatic nerve	30°	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	<.001**	1	0.92	0.555
	60°	-	-	-	0.004*	0.002*	0.003*	0.943	1	0.698	<.001**	<.001**	0.011*
	90°				-	-	-	0.163	0.02*	0.254	<.001**	<.001**	<.001**
	120°							-	-	-	<.001**	0.002*	<.001*
	150°										-	-	-

Comparisons between each measurement point at the hip joint in the extension, neutral, and flexion positions were made by one-way analysis of variance (ANOVA), and post-hoc tests were performed using the Tukey–Kramer method. *p<0.05, **p<0.001.

Table 2. *P*-values for pairwise comparison between the distances of extension, neutral, and flexion.

Comparisons between each hip position		30°			60°			90°			120°			150°		
		Extension	Neutral	Flexion	Extension	Neutral	Flexion	Extension	Neutral	Flexion	Extension	Neutral	Flexion	Extension	Neutral	Flexion
Femoral nerve	Extension	-	0.049*	<.001**	-	0.039*	<.001**	-	<.001**	<.001**	-	<.001**	<.001**	-	<.001**	<.001**
	Neutral		-	0.368		-	0.016*		-	<.001**		-	<.001**		-	0.026*
	Flexion			-			-			-			-			-
Sciatic nerve	Extension	-	0.08	<.001**	-	<.001**	<.001**	-	<.001**	<.001**	-	0.019*	<.001**	-	0.008*	<.001**
	Neutral		-	0.005*		-	<.001**		-	<.001**		-	<.001**		-	<.001**
	Flexion			-			-			-			-			-

The *p*-values for the comparison of the extension, neutral and flexion positions at each measurement point are shown.
Repeated measures analysis of variance was used, followed by multiple comparisons using the Tukey-Kramer method.
*$p<0.05$, **$p<0.001$.

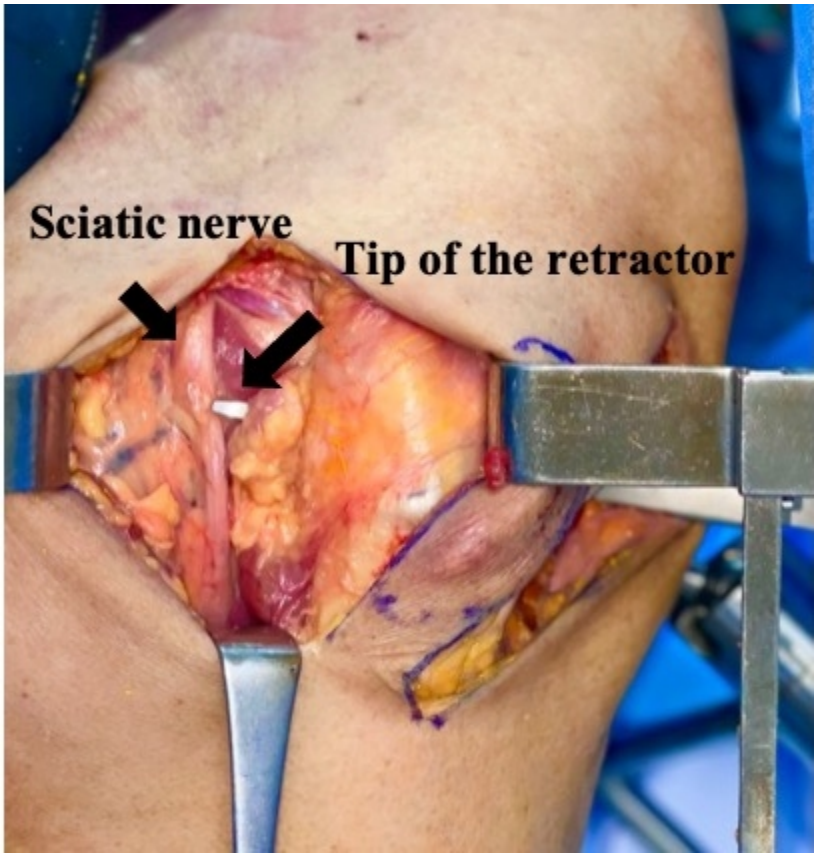

Fig. 1 Incorrect retractor insertion into the posterior acetabulum

The tip of the retractor penetrates the posterior joint capsule and the short external rotator muscls. This can cause direct injury to the sciatic nerve.

143x149mm (72 x 72 DPI)

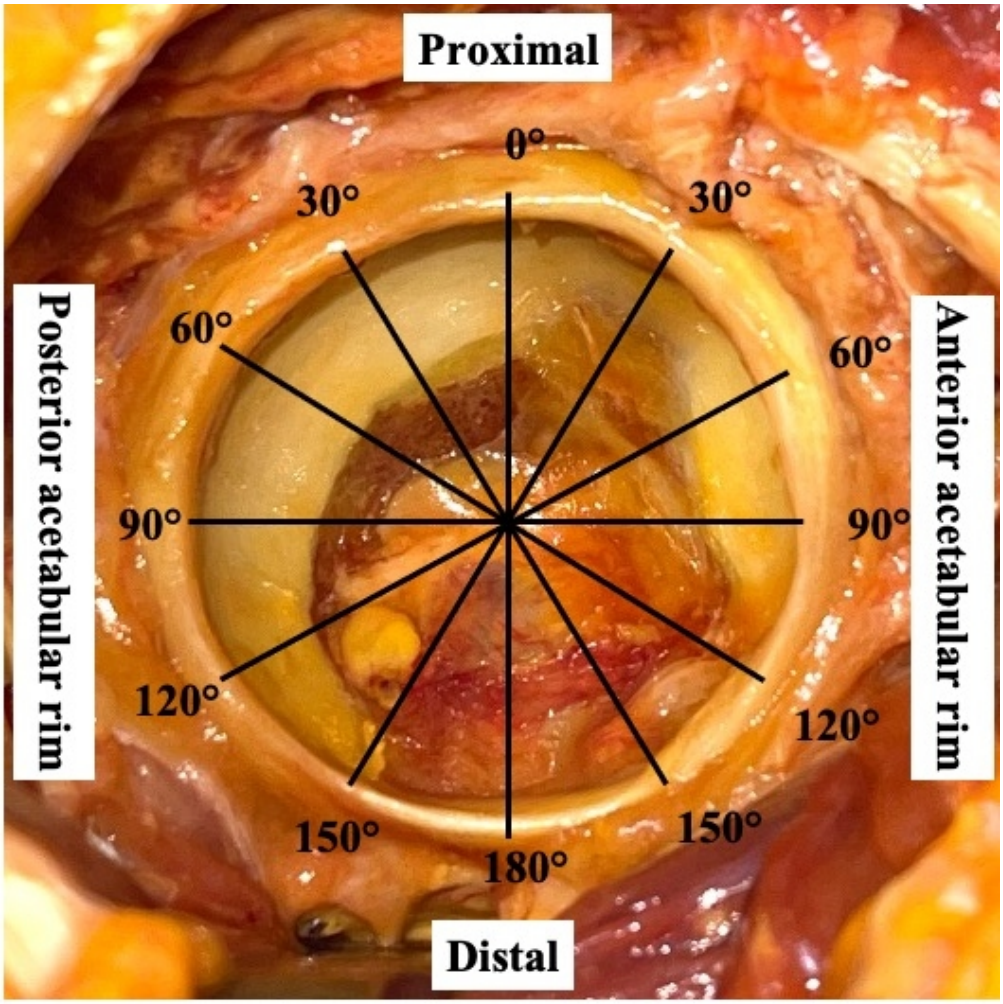

Fig. 2 Lateral view of the right acetabulum

A reference line was drawn through the centre of the acetabulum and the centre of the transverse ligament. Its intersection with the superior and inferior margin of the acetabulum was defined as 0^0 and 180^0, respectively.
A total of 10 measurement points were established, five at every 30^0 anterior margin of the acetabulum and five at every 30^0 posterior margin of the acetabulum.

186x187mm (72 x 72 DPI)

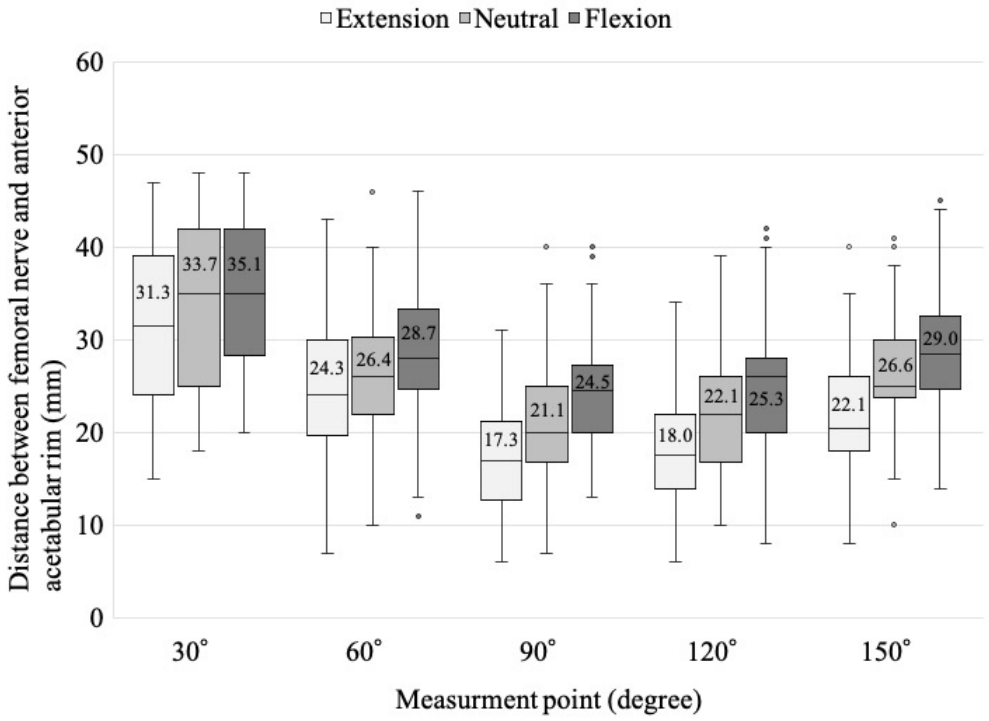

Fig. 3 Distance between femoral nerve and anterior acetabular rim (mm)

The box plots show the distances between the femoral nerve and anterior acetabulum at each measurement point. The numbers on the boxes indicate means, the bottom and top of the boxes indicate the 25th and 75th percentiles, and the horizontal line within indicates the median. The limits of the whiskers indicate the values within the 1.5 interquartile range above and below the boxes, and the dots indicate outliers.

251x185mm (72 x 72 DPI)

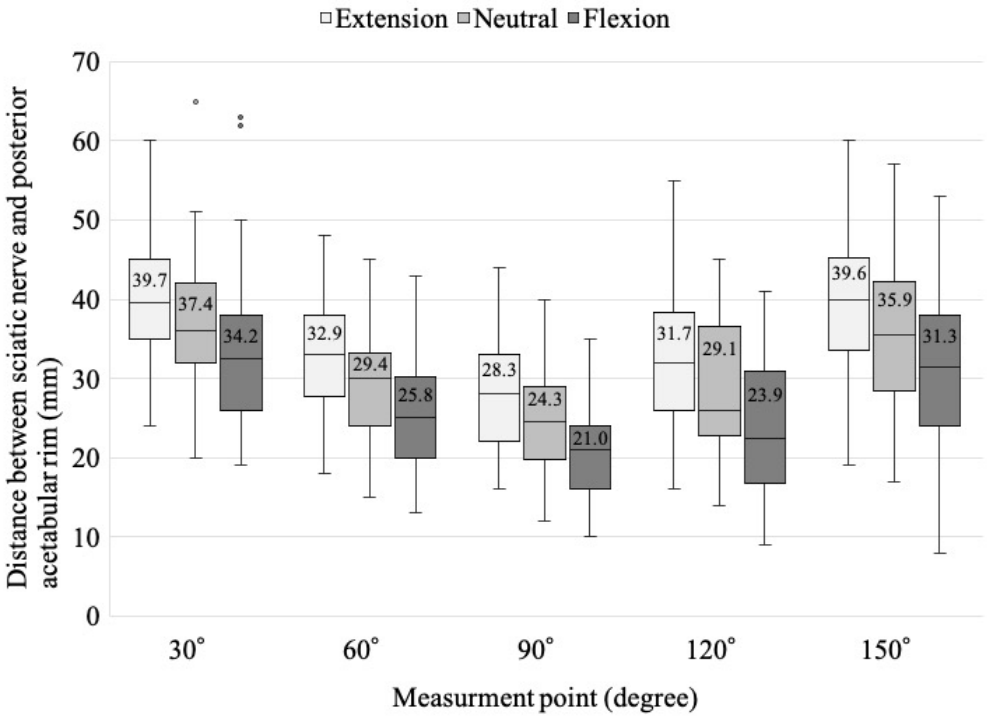

Fig. 4 Distance between sciatic nerve and posterior acetabular rim (mm)

The box plots show the distances between the sciatic nerve and posterior acetabulum at each measurement point. The numbers on the boxes indicate means, the bottom and top of the boxes indicate the 25th and 75th percentiles, and the horizontal line within indicates the median. The limits of the whiskers indicate the values within the 1.5 interquartile range above and below the boxes, and the dots indicate outliers.

252x185mm (72 x 72 DPI)