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Sciatic nerve movement in the deep gluteal space during hip rotations maneuvers

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Abstract

We hypothesize that the sciatic nerve in the subgluteal space has a specific behavior during internal and external coxofemoral rotation and during isometric contraction of the internal and external rotator muscles of the hip. In 58 healthy volunteers, sciatic nerve behavior was studied by ultrasound during passive internal and external hip rotation movements and during isometric contraction of internal and external rotators. Using MATLAB software, changes in nerve curvature at the beginning and end of each exercise were evaluated for longitudinal catches and axial movement for transverse catches. In the long axis, it was observed that during the passive internal rotation and during the isometric contraction of external rotators, the shape of the curve increased significantly while during the passive external rotation and the isometric contraction of the internal rotators the curvature flattened out. During passive movements in internal rotation, on the short axis, the nerve tended to move laterally and forward, while during external rotation the tendency of the nerve was to move toward a medial and backward position. During the isometric exercises, this displacement was less in the passive movements. Passive movements of hip rotation and isometric contraction of the muscles affect the sciatic nerve in the subgluteal space. Retrotrochanteric pain may be related to both the shear effect of the subgluteus muscles and the endoneural and mechanosensitive aggression to which the sciatic nerve is subjected.

KEYWORDS
hip joint, isometric contraction, pain, rotation, sciatic nerve, ultrasonography

1 | INTRODUCTION

Retrotrochanteric or deep gluteal pain has conventionally been related to the sciatic nerve. This nerve can be compromised by pathologies of the piriformis muscle (Barton, 1991; Güvençer et al., 2008; Smoll, 2010; Steiner et al., 1987), the internal gemelli-obturator

Location where the research was performed: Consell Català de l'Esport, Generalitat de Catalunya, Barcelona, Spain.

internus complex (Balius et al., 2018; Filler & Gilmer-Hill, 2009; Meknas et al., 2003, 2009, 2011; Murata et al., 2009), ischio-femoral impingement (Fernández-Hernando et al., 2015; Taneja et al., 2013) and injuries to the hamstring insertion (Bucknor et al., 2014; Fernández-Hernando et al., 2015). Since the beginning of the century, neurodynamics has emerged as a tool for therapeutic and health purposes. Nowadays, neurodynamic tests and treatments are suitable for all major nerves (Shacklock et al., 2007). The neurodynamic characteristics of the sciatic nerve have been evaluated, especially regarding its displacement during flexion-extension movements of the hip (Coppieters et al., 2015), the knee (Coppieters et al., 2015; Ellis et al., 2012), and even the cervical spine (Ellis et al., 2012), but only in one publication have they been related to coxofemoral rotations (Balius et al., 2018). The behavior of the sciatic nerve at this level has not been studied sufficiently.

The objective of the present study was to examine the normal longitudinal and transverse behavior of the sciatic nerve in the deep gluteal space during internal and external rotations of the hip and during isometric contractions of both the internal and external rotators, using high-resolution ultrasound.

2 | MATERIAL AND METHOD

2.1 | Participants

A total of 58 healthy volunteers, mainly young athletes, were included in the study: 30 men and 28 women, mean age 20.4 ± 7.7 years (range 18–54), height 176.4 ± 8.6 cm, weight 66.6 ± 9.8 kg, body mass index 21.4 ± 2.4 kg/m^2. The participants met the inclusion criteria: they were healthy, over 18 years old, and had no previous pelvic and/or hip disorders or symptoms suggestive of sciatic nerve dysfunction. Participants were excluded if they had a history of major trauma or surgery in the lumbar, hip, gluteal, or hamstring enthesis, a negative straight leg raise test, or sciatic nerve impairment. They were also excluded if they had any disorder that could alter nervous system functions.

2.2 | Imaging

Movements of the sciatic nerve were assessed by ultrasound at the deep gluteal space. Shape changes between the beginning and end of different neural mobilization exercises were quantified in terms of: (a) the degree of curvature of the nerve in longitudinal view, (b) axial motion in transverse view. An initial short-axis imaging test on the posterior buttock was used to locate the sciatic nerve precisely along the obturator internus tendon. Once the nerve was identified, the probe was rotated until it was located on the long axis. The slice was from the point at which the nerve exited below the piriformis muscle toward the distal area, covering the gemelli-obturator internus complex and the proximal section of the quadratus femoris. A single examiner with 25 years' experience in ultrasound conducted all the ultrasound tests.

The high ultrasound machine (TUS-A500 "Aplio 500" 5.0 Platinum; Canon Medical Systems Corporation; Nasu, Japan) was fitted with a high-frequency linear array probe (PLT-1005BT linear array, frequency range 5–14 MHz). Preset characteristics were a depth of 5 cm, with single focus at 1.8 cm and dynamic range of 69%. A video of the nerve movement was recorded for each exercise trial. The video sequence had a capture rate of 30 frames per second. Two representative frames (beginning and end of the exercise) were manually selected for analysis in each video. A different senior analyst segmented the sciatic nerve manually on the images.

In longitudinal captures, the nerve appeared as a band in the ultrasound images (Figure 1a). MATLAB (The MathWorks Inc, Natick, MA) software was used first to compute the medial axis of this band as the representative curve of the nerve and then to calculate its curvature (Alex et al., 2008). The curvature κ of a point $P=(x(t),y(t))$ on a curve is defined as the inverse of the radius of the circle tangent to the curve at that Point (A). It can be computed from the coordinate derivatives using the formula

$$\kappa=\frac{x'y''-x''y'}{\sqrt{\left(x'^2+y'^2\right)^3}}, \tag{A}$$

The curvature of a curve is a good descriptor of its local shape and allows us to compare the shape of the sciatic nerve between the beginning and end of the motion. A curvature value $\kappa=0$ is associated to indicate a flat curve (a straight line) and nonzero values correspond to proper curves. Positive and negative curvature values correspond to convex or concave parts of the curve, respectively.

In transverse image capture, the sciatic nerve appeared as an elliptical closed loop in the ultrasound images. MATLAB software was used to segment it, and its centroid was determined as a representative point on the nerve in each image. Owing to possible misalignments during movement recording, a bone reference point was marked on the ischium corresponding to the most lateral edge of the acetabulum (Figure 1b).

As a result of this segmentation process, a closed elliptical loop represented the cross-section of the nerve, and the centroid of these points was taken as the representative point for the nerve. The initial relative position of the centroid was compared with that at the end of each rotation movement. The previously acquired bone reference was placed at the origin of the coordinates, enabling the movement between the initial and final positions to be estimated.

2.3 | Hip mobilization exercises and evaluation

Participant set-up. The volunteer was stretched on the examination table in the prone position and their pelvis was secured by straps, leaving the buttocks free, in order to fix the lumbar area and the pelvis during hip mobilization. The knee was placed at 90° of flexion. Each participant made a total of four different movements. First, a passive external and internal coxofemoral rotation was performed and the angle of rotation was measured using a pendulum goniometer (Basson et al., 2015; Vila-Viñas et al., 2014). Subsequently, with an assistant

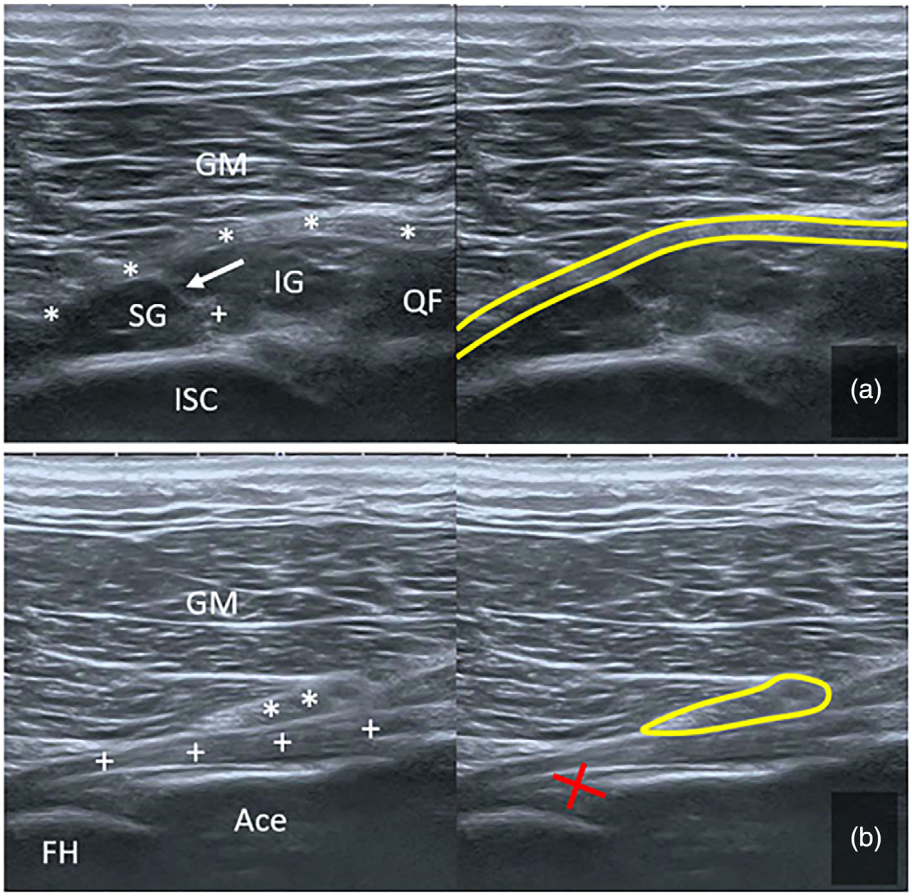

FIGURE 1 Ultrasound study of the sciatic nerve in the deep gluteal space in the neutral position. (A) Long axis slice distal to the exit of the sciatic nerve below the piriformis muscle. (B) Short-axis slice just above the obturator internus muscle tendon. The images on the left are not processed. The images on the right show the segmented sciatic nerve in yellow; the red cross indicates a reference point on the lateral margin of the acetabulum. (*), sciatic nerve; (+), obturator internus tendon; FH, femoral head; IG, inferior gemellus muscle; ISC, ischium bone; QF, quadratus femoris muscle; ace, acetabulum; SG, superior gemellus muscle; arrow, connective anchor between the sciatic nerve and the obturator internus tendon

holding the studied limb at 90° of knee flexion, an external and internal coxofemoral isometric strength test was performed, quantifying the force with a "Commander Muscle Tester" (JTECH-Medical; Midvale, USA) and selecting the highest value obtained (Thorborg et al., 2010).

While these various actions were performed, the behavior of the sciatic nerve was assessed by ultrasound in both long and short-axis views. Passive maneuvers were performed at least twice, while isometric maneuvers were performed three times each. The replicate with the best ultrasound record was chosen.

Instead of studying craniocaudal displacement of the sciatic nerve, we focused on describing the nerve shape during an internal or external rotation of the hip or an isometric contraction of the internal or external rotators. Movements were recorded on the long and short axes in order to elucidate the conditioning of the overall movement and shape of the nerve by surrounding anatomical structures. Initial curve measurements for all participants were compared with the final measurements on both the long and short axes, after the four specific movements performed were chosen.

2.4 | Statistics

The significances of the curve and movement measurements were assessed using the Wilcoxon signed-rank test and MATLAB R2018a Update 2 software.

3 | RESULTS

When the initial and final measurements for the two curves were compared (Table 1), there were significant differences ($p < 0.050e-2$) in the amplitude and mean values of each (Figure 2). The largest difference was for passive internal rotation (PAS INT ROT), both left and right (Figure 3), and isometric external rotation (ISO EXT ROT), both left and right, with similar curve behaviors (Figure 4).

There was no statistically significant relationship between the degree of deformation of the curve and the angle of internal or external rotation of the hip ($p = 0.15$). In addition, there was no statistical correlation between the deformity of the curve and the isometric contraction strength of the rotators ($p = 0.25$).

The transverse movement of the sciatic nerve was studied through short-axis ultrasound imaging tests. Owing to technical problems, only 51 of the 58 participants recruited were recorded and finally included. All volunteers showed relative symmetry between the movements of the two hips along both the abscissa and the ordinate (Figure 5). Thus, internal rotation dynamic movements showed that the sciatic nerve tended to move laterally and forwards, while during external rotation its tendency was to move medially and backward (Figure 6). Neural translation movements during isometry (Figure 7) showed a smaller displacement than during dynamic movements (Table 2).

TABLE 1 Mean and standard deviation (Std) values of the curvature for the initial and final curves (Kappa) corresponding to each movement

	κ -initial (10^{-3})		κ -final (10^{-3})		κ -variation (10^{-3})	
Type of motion	Mean	Std	Mean	Std	Mean	Std
R_PAS_EXT_ROT	3.03	1.36	2.17	1.12	−0.86	1.53
R_PAS_INT_ROT	3.14	1.45	6.2	2.45	3.06	2.33
R_ISO_EXT_ROT	3.08	1.27	6.3	1.68	3.22	1.98
R_ISO_INT_ROT	2.73	0.93	2.65	1.14	−0.08	1.24
L_PAS_EXT_ROT	2.74	1.26	2.17	1.01	−0.57	1.57
L_PAS_INT_ROT	2.46	0.83	5.3	1.66	2.84	1.90
L_ISO_EXT_ROT	3.16	1.41	6.02	1.88	2.86	2.37
L_ISO_INT_ROT	2.78	1.22	2.91	2.14	0.13	2.52

Abbreviations: L ISO EXT ROT, left isometric internal rotators; L ISO INT ROT, left isometric internal rotators; L PAS EXT ROT, left passive external rotation; L PAS INT ROT, left passive internal rotation; R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators; R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation.

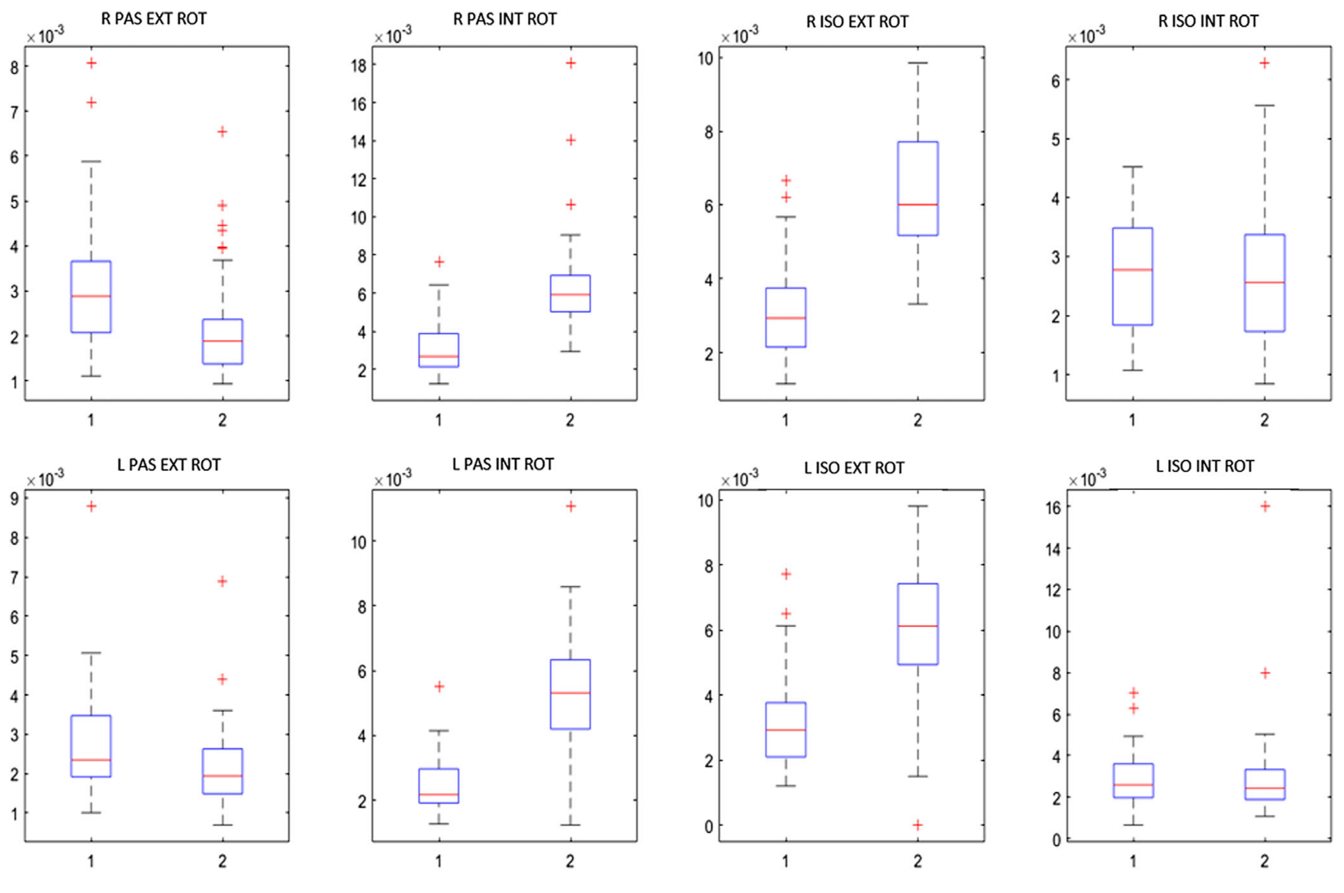

FIGURE 2 Statistical boxplot representation of the curvatures values of the sciatic nerve in all the participants. The curvatures of the initial and final shapes of the nerve are shown for each type of motion. In each box, the central mark (red line) is the median, the edges are the 25th and 75th percentiles, and the whiskers extend to the most extreme data points. Outliers are not considered and are plotted individually (red cross). Significant differences in mean values between the starting and final positions, mainly for the second and third columns. L ISO EXT ROT, left isometric internal rotators; L ISO INT ROT, left isometric internal rotators; L PAS EXT ROT, left passive external rotation; L PAS INT ROT, left passive internal rotation; R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators; R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation

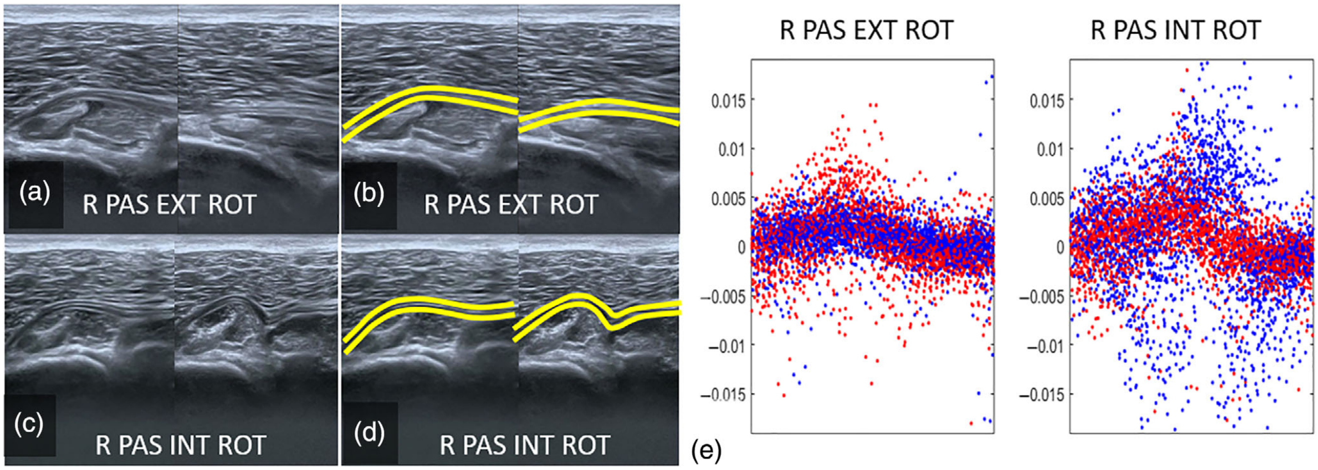

FIGURE 3 Long axis study of right sciatic nerve during passive external and internal rotation maneuvers. (A) Initial (left) and final (right) frames for the external hip rotation (R PAS EXT ROT). (B) Sciatic nerve is segmented in yellow. (C) Initial (left) and final (right) frames for the external hip rotation. (R PAS INT ROT) (D) Sciatic nerve is segmented in yellow. (E) Curvature values for the sciatic nerve; red dots are associated with the starting position of the nerve and blue ones with the final position after the motion. Curvature values for both curves over all participants. In the R PAS INT ROT (E-right), it can be seen that the red dots are concentrated near-zero values while the blue ones reach higher values. R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation

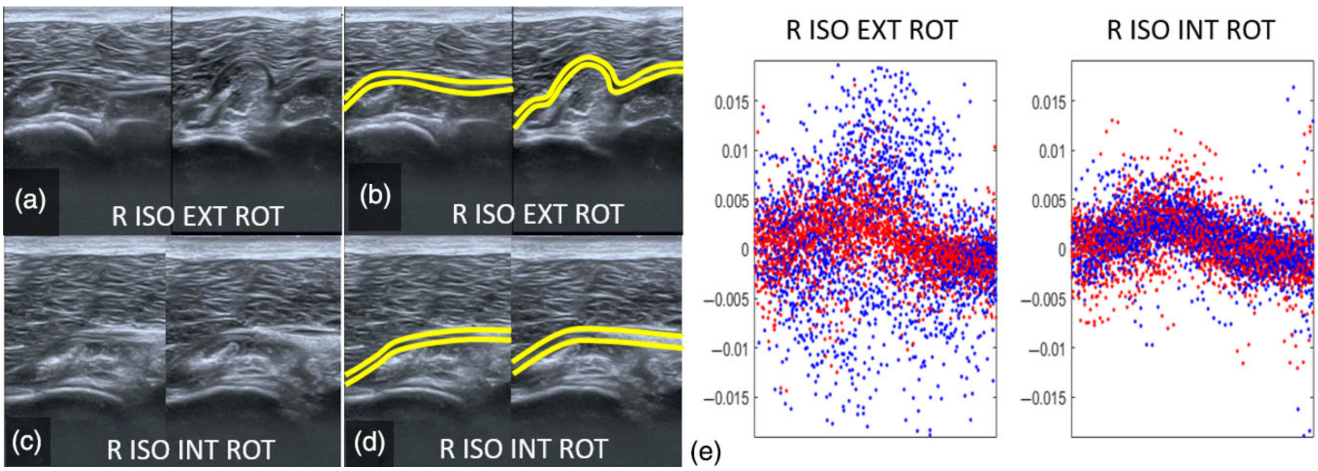

FIGURE 4 Long axis study of the right sciatic nerve during isometric contraction of the external and internal rotators. (A) Initial (left) and end (right) frames for isometric contraction of the external rotators (R ISO EXT ROT). (B) Sciatic nerve is segmented in yellow. (C) Initial (left) and end (right) frames for isometric contraction of the internal rotators (R ISO INT ROT) (D) Sciatic nerve is segmented in yellow. (E) Curvature values for the sciatic nerve. Red dots are associated with the starting position of the nerve and blue ones with the final position after the motion. R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators

There was no statistical correlation between the neural translation movements and the isometric contraction strength of the rotators ($p = 0.25$).

4 | DISCUSSION

This study demonstrates that the sciatic nerve is deformed in the deep gluteal space, especially during dynamic coxofemoral internal rotation movements and even more during isometric contraction of the external rotators (Video S1). Similarly, small displacements of the sciatic nerve were observed on the axial axis.

Until recent years, pseudo-sciatica or localized pain in the buttock, with or without radiation to the thigh, has been related to sciatic entrapment at the level of the piriformis muscle (Piriformis syndrome) (Hopayian et al., 2010), especially when the sciatic nerve has a variant anatomy (Poutoglidou et al., 2020). Pećina (1979) found that in 6.15% of cases the nervus peroneus communis passes between the tendinous parts of the piriformis, and they considered this variation of practical significance for the development of “piriformis syndrome.”

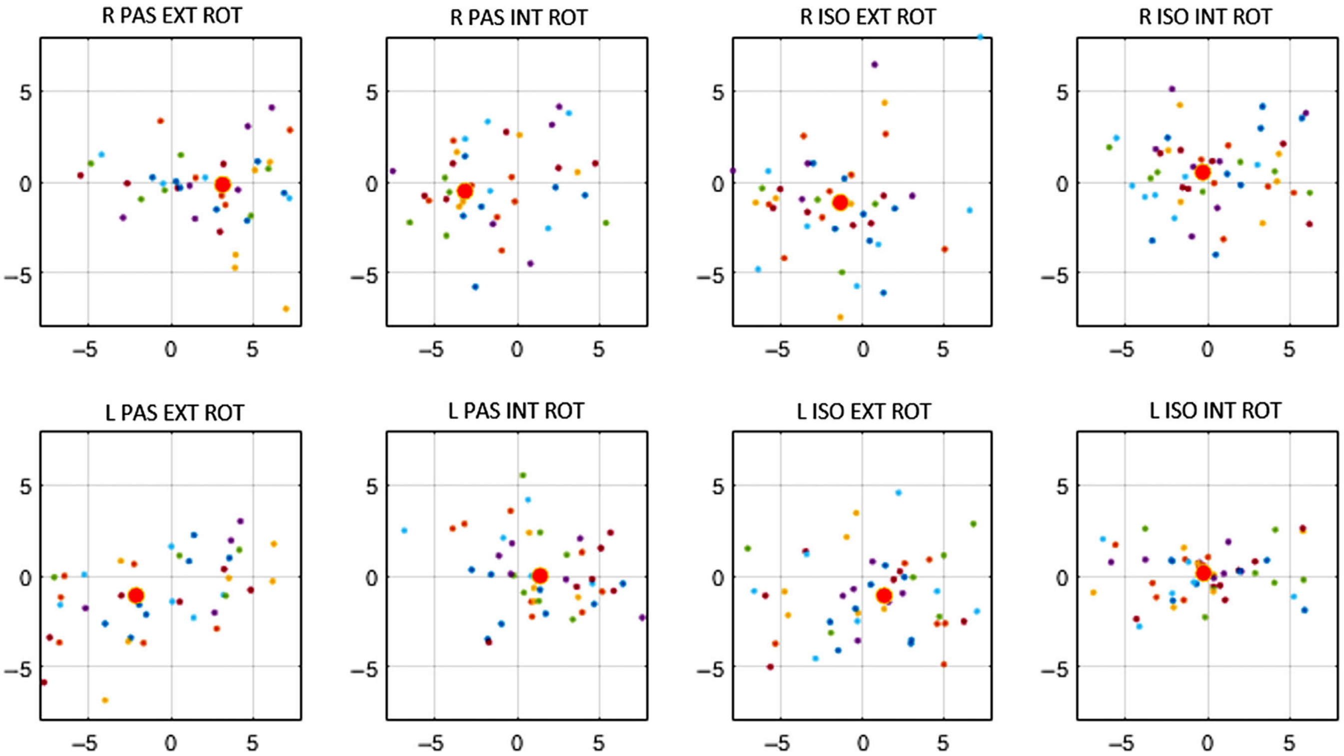

FIGURE 5 Short-axis study of the right sciatic nerve during all movements. Each point represents the relative motion between the centroid of the transverse section of the nerve and the anchor point for each participant. The big red marker is the median value of these points. The scale (X, Y) is in millimeters. The movements of the two hips are relatively symmetrical (first row images compared with the corresponding ones in the second row) L ISO EXT ROT, left isometric internal rotators; L ISO INT ROT, left isometric internal rotators; L PAS EXT ROT, left passive external rotation; L PAS INT ROT, left passive internal rotation; R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators; R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation

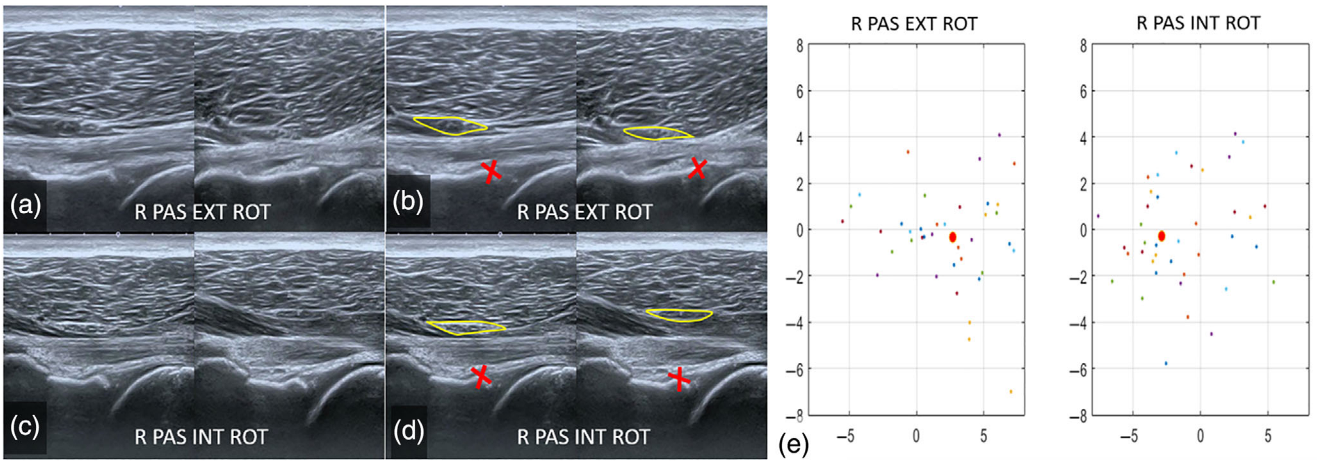

FIGURE 6 Short-axis study of the right sciatic nerve during passive external and internal rotation maneuvers. (A) Initial (left) and end (right) frames for external hip rotation (R PAS EXT ROT). (B) Sciatic nerve is segmented in yellow and the anchor point in red. (C) Initial (left) and final (right) frames for external hip rotation (R PAS INT ROT) (D) Sciatic nerve is segmented in yellow and the anchor point in red. (E) Recorded transverse motion of the sciatic nerve during the different rotation exercises. Each point represents the relative motion between the centroid of the transverse section of the nerve and the anchor point for each participant. The big red marker is the median value of these points. The scales (X, Y) of the plots are in millimeters. R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation

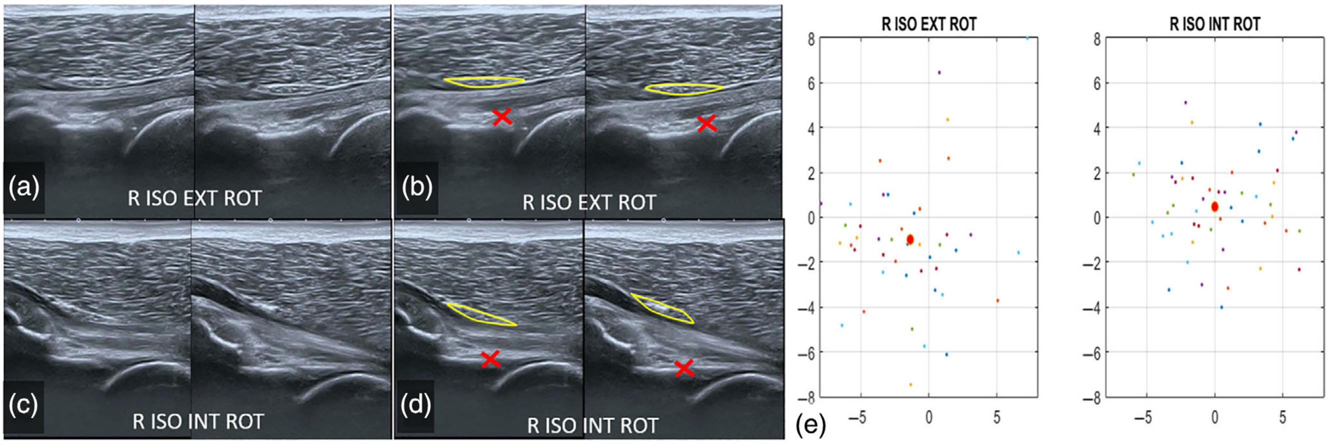

FIGURE 7 Long axis study of the right sciatic nerve during isometric contraction of the external and internal rotators. (A) Initial (left) and final (right) frames for isometric contraction of the external rotators (R ISO EXT ROT). (B) Sciatic nerve is segmented in yellow. (C) Initial (left) and final (right) frames for isometric contraction of the internal rotators (R ISO INT ROT) (D) Sciatic nerve is segmented in yellow. (E) Recorded transverse motion of the sciatic nerve during the different rotation exercises. Each point represents the relative motion between the centroid of the transverse section of the nerve and the anchor point for each participant. The big red marker is the median value of these points. The scales (X, Y) of the plots are in millimeters. R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators

During internal rotation of the thigh, the piriformis is extended, and the tendons of the divided muscle are tightly pressed together, pinching the nerve between them. This variant was absent in our series, but the sciatic nerve shows a consistent bending behavior that could also, in certain situations, contribute to the appearance of symptoms. Nowadays, the origin of pain in the deep gluteal space is more broadly identified, implicating other hip rotator muscles. Thus, the concept of the deep gluteal syndrome was proposed (Hu et al., 2021). This increasingly recognized syndrome has changed the classical concept of pyramidal syndrome, elucidating its pathophysiological mechanism. The present article provides a dynamic perspective on the behavior of the normal sciatic nerve during rotation maneuvers of the coxofemoral joint, indicating that in future years its evaluation will facilitate the assessment of its possible significance for diagnosing pain in the buttock (Hu et al., 2021).

The neurodynamic characteristics of the sciatic nerve have been studied mainly at the level of the thigh. Ellis et al. (2012) assessed knee extension along with cervical flexion-extension and detected a craniocaudal movement of 2.6 ± 1.4 mm, whereas Coppieters et al. (2015) reported displacements of between 3.2 ± 2.1 mm and 17.0 ± 5.2 mm in combined flexion and extension hip or knee movements. Sciatic nerve behavior has also been studied during the Straight Leg Raise Test (Ridehalgh et al., 2015), resulting in a displacement of 12.5 ± 1.4 mm. To date, all research has focused on joint flexion-extension movements at different levels, but never during rotation movements. The effect of passive hip rotation on the sciatic nerve has only been researched by Balius et al. (2018), who showed that during passive internal rotation the sciatic nerve transformed from a straight to a curved structure. In addition, normal sciatic nerve behavior has never been assessed during contraction of the hip rotator muscles. Our study goal was primarily focused on those muscles.

Balius et al. (2018) revealed a specific connective anchorage from the sciatic nerve to the obturator internus tendon in a cadaver. This anchorage constrains the behavior of the nerve during passive internal and external rotation movements of the hip. In the cadaver, and in 31 healthy volunteers, the sciatic nerve traced a downward curve following the obturator internus tendon during internal rotation. In contrast, external hip rotation caused the nerve to stretch. The same behavior was observed in the 58 healthy volunteers in our study (Figure 8). In addition, high-resolution ultrasound demonstrated the internal sciatic-obturator connective anchorage described by Balius et al. (2018) in many of our young healthy subjects (Figure 1a). This study also assessed short-axis sciatic nerve behavior and showed that during internal rotation the obturator tendon anchorage pulls the sciatic nerve outwards and forwards while the external rotation movement pulls it in the opposite direction.

A dynamic body movement entails the involvement of several joints and leads to specific muscle movements, but passive stabilization can also be involved. The nervous system is usually ignored. Thus, a nerve moves to adapt to body movement and maintains its own transmission function (Munne & Pedret, 2018). During daily activities, movements and postures that our body adopts generate tension, compression, and shear forces on the nervous system. Under normal circumstances, the nervous system has the biomechanical ability to adapt to those forces and continue to perform its functions (Silva et al., 2014). The structural organization of the peripheral nerves allows axons to conduct nerve impulses that will facilitate a person's interactions with the environment while directing and tolerating thousands of torso, head, and limb postures (Munne & Pedret, 2018).

The present study shows normal and specific sciatic nerve behavior during isometric contraction of the external and internal rotator muscles of the hip. External rotators increase their volume by contracting (specifically the gemelli, the internal obturator, and the

TABLE 2 Mean relative displacements values for the initial and final images corresponding to each type of movement

	Relative *x*-displacement		Relative *y*-displacement	
Type of motion	Mean	Std	Mean	Std
R_PAS_EXT_ROT	−0.15	2.05	3.16	4.21
R_PAS_INT_ROT	−0.52	2.61	−3.12	5.34
R_ISO_EXT_ROT	−1.15	2.76	−1.34	4.84
R_ISO_INT_ROT	0.53	2.02	−0.29	4.21
L_PAS_EXT_ROT	−1.09	2.15	−2.12	6.66
L_PAS_INT_ROT	−0.004	2.04	1.42	3.96
L_ISO_EXT_ROT	−1.09	2.37	1.35	5.58
L_ISO_INT_ROT	0.15	1.44	−0.24	3.55

Abbreviations: L ISO EXT ROT, left isometric internal rotators; L ISO INT ROT, left isometric internal rotators; L PAS EXT ROT, left passive external rotation; L PAS INT ROT, left passive internal rotation; R ISO EXT ROT, right isometric internal rotators; R ISO INT ROT, right isometric internal rotators; R PAS EXT ROT, right passive external rotation; R PAS INT ROT, right passive internal rotation.

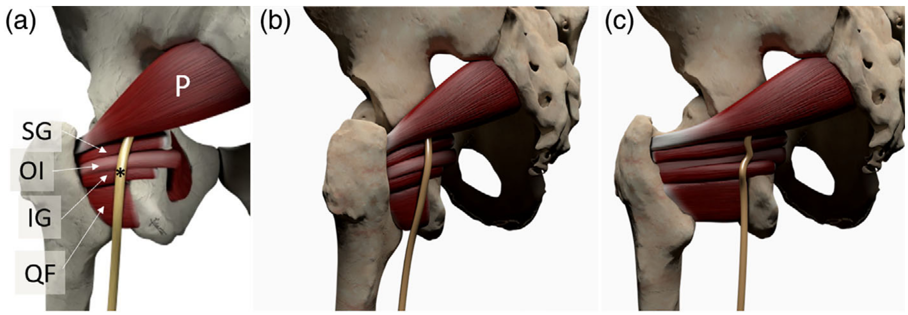

FIGURE 8 Neural translation during hip rotations. (A) Neutral position. (B) External rotation; the tendon of the obturator internus lacks tension and the sciatic nerve relaxes, becoming straighter. (C) Internal rotation; the tendon of the obturator internus and gemelli tightens, followed by the sciatic nerve, which becomes curved. IG, inferior gemellus muscle; OI, obturator internus muscle; P, piriformis muscle; QF, quadratus femoris muscle; SG, superior gemellus muscle; (*), sciatic nerve

quadratus femoris), causing the sciatic nerve dorsal to them to bulge to a posterior direction to adapt to the muscle dynamics. In contrast, the obturator internus tendon, owing to its anatomical arrangement, is tensioned in the opposite (anterior) direction. This combination of increased volume of the gluteal muscles in the posterior direction with the tension of the internal obturator tendon in the anterior direction increases the sciatic nerve curvature significantly and repeatedly deforms it during isometric contraction movements. Conversely, during isometric contraction of the hip internal rotator muscles, the nerve tends to stretch (Figure 9).

This alteration of behavior in response to both excess and deficit could change the mechanosensitivity and endoneural health of the nerve. Intraneural tissue (axon, endoneurium, and blood vessels) does not have the same flexibility as its interfaces. Consequently, these structures have a retracting or rippling arrangement in the rest position. When a movement is initiated, the endoneurial tissue lengthens (Butler & Coppieters, 2007; Paillant, 2003). Sustaining the stretching of the nerve bed and/or exceeding its limits impairs nerve function. A lengthening of 5%–10% impairs small vessel blood flow and 15% interrupts it (Butler & Coppieters, 2007; Coppieters et al., 2006; Lundborg, 1988; Lundborg & Dahlin, 1996). Keeping the nerve bed stretched at 6% for an hour causes a 70% reduction in nerve conduction. The longer this stretch is maintained, the longer complete recovery will take, and the more likely side effects are to appear (Lundborg, 1988). It seems reasonable to propose that repeated deformation of the sciatic nerve beyond the behavior observed in this study could produce harmful mechanosensitivity and endoneural effects.

Most nerves are surrounded by adipose tissue and not in direct contact with the epimysium of muscle. The microanatomy of successive cross-sections allows those details to be seen. They are not visible with 8–12 MHz ultrasound probes, which misleadingly show the muscle in direct contact with nerves. This fat is necessary to preserve the nerve's displacement between neighboring structures (muscle, bone, and joints) by decreasing the friction (Reina et al., 2020). Thus, there are commonly adaptive changes in the structure of the nerve covering to protect the axons following chronic injuries under normal and pathological conditions: increases in the thickness of the perineurium and epineurium and in the amount of adipose tissue inside and outside the nerve, and between the fascicles and within the

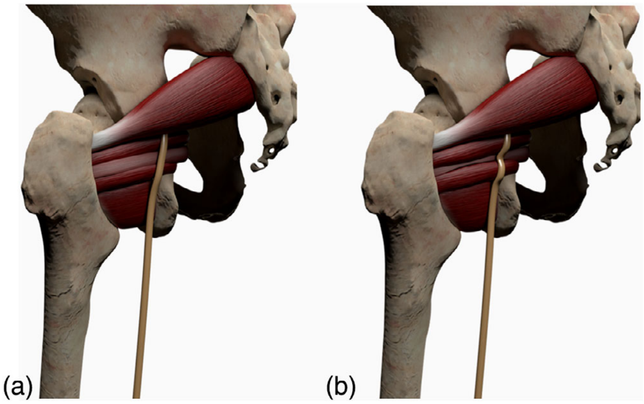

FIGURE 9 Neural translation during isometry. (A) During an isometric contraction of the internal rotator muscles, the nerve is more tense but the external rotators are relaxed. (B) Conversely, during an isometric contraction of the external rotator muscles, the nerve is highly curved because the muscle has increased in volume and the obturator internus tendon is tense, pulling the nerve down (i.e., anteriorly) while the muscles push it upward (i.e., posteriorly)

paraneural (circumneural) compartments (concentrical fat compartment surrounding the nerve). These structural changes undoubtedly occur along the studied portion of the nerve. It is well known that the internal microstructure of a trapped nerve is disrupted (echogenicity changes, increased sectional area proximal to entrapping areas, alterations in neurodynamics, etc.) (Gervasio et al., 2020). The new high-resolution ultrasound machines can allow the sciatic nerve to be examined accurately in the deep gluteal space. A skilled examiner can easily evaluate the nerve in gray scale, and the specificity can be improved by a dynamic evaluation with rotational movements of the hip, which could elucidate the pathogenesis of deep gluteal syndrome.

On the other hand, the "scissor effect" is classically referenced as the cause of sciatic nerve entrapment by passing under the piriformis muscle belly and over the gemelli-obturator internus complex (Ergun & Lakadamyali, 2010; Fernández-Hernando et al., 2015, 2016; Pérez-Carro et al., 2016). The present study shows that this effect is more complex than initially described. There is not only a shear effect between these muscles; the gemelli-obturator internus complex also pulls the nerve in the sagittal plane, moving it in the coronal plane, while the piriformis blocks this movement.

Currently, pain at this level is classed as "deep gluteal pain" (Fernández-Hernando et al., 2015, 2016; Kizaki et al., 2020; Martin et al., 2011; Pérez-Carro et al., 2016). This indicates the etiopathogenic complexity of the process and therefore its symptoms and exploration. In daily clinical practice, it is uncommon for imaging to reveal any impairment at this level. Therefore, it is first essential to know that normal nerve behavior is related to the movements of the surrounding joints. Once the normal behavior of the sciatic nerve in the deep gluteal space is known, we suggest that further studies on patients with retrotrochanteric pain should be performed (Martin et al., 2014). If nerve motion/shaping is found to differ in symptomatic patients, a hypothesis about the association with retrotrochanteric pain or other pain conditions could be proposed.

5 | CONCLUSION

To sum up, the present work reveals the normal behavior of the sciatic nerve during rotational movements of the hip and (for the first time) during isometric contraction of the rotator muscles of the hip. The assessment of this behavior in pathological situations would allow the pathogenic basis of gluteal pain, which is currently uncertain, to be better understood.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all participants.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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