

ULTRASOUND APPEARS TO BE A RELIABLE TECHNIQUE FOR THE DIAGNOSIS OF PIRIFORMIS SYNDROME

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ABSTRACT: *Introduction:* Piriformis muscle syndrome (PS) is a disorder encompassing a constellation of symptoms, including buttock and hip pain. In this study we aimed to assess the value of ultrasound (US) in the diagnosis of PS. *Methods:* Thirty-three clinically diagnosed PS patients and 26 healthy volunteers underwent a clinical PS scoring examination and US and MRI assessment of the bilateral piriformis muscles. The areas under the receiver operating characteristic curves (AUROCs) of the US parameters (i.e., increased thickness [iTh] and increased cross-sectional area [iCSA]) for piriformis muscle were evaluated. *Results:* On US and MRI, the thickness and CSA were increased in PS patients. The AUROCs for the iTh and iCSA for discriminating stage 0 (healthy volunteers) from stage 1 through stage 3 (PS patients) were 0.88 and 0.95, respectively. *Discussion:* US may be a reliable technique for the clinical diagnosis of PS.

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Piriformis muscle syndrome (PS), is a disorder encompassing a constellation of symptoms, including buttock or hip pain. It has been described for over 500 years, yet it remains controversial.^{1–3} PS is more frequently encountered in middle-aged patients and is rarely seen in patients younger than 20 years of age.^{4,5}

There are several methods for the diagnosis of PS. Clinically, tenderness with palpation over the piriformis muscle is common. In the Pace test, pain is elicited on resisted leg abduction while seated. The Freiberg test is a passive maneuver in which a forceful internal rotation of the extended thigh induces buttock pain by stretching the piriformis muscle.^{5,6} Notably, the Freiberg and Pace tests are positive in only 67% of patients.⁵ Michel *et al.* proposed a scoring system consisting of clinical symptoms, signs, and several provocative maneuvers for PS diagnosis.^{7–9} The

sensitivity and specificity of this system were 96.4% and 100%, respectively.

Ultrasound (US), computed tomography (CT), electromyography (EMG),¹⁰ and magnetic resonance imaging (MRI) have been used to diagnose PS.^{7,11–15} It is difficult to visualize subtle changes in muscle and soft tissue with CT,⁷ and MRI¹² provides a far more detailed evaluation. US, which exhibits promise in guiding muscle injections,^{16–18} is more convenient, with no radiation exposure. However, only a few case report studies have used US for PS diagnosis,^{19,20} and a systematic study of US diagnosis evaluation of the piriformis muscle in PS has not yet been reported.

In this study we aimed to assess the piriformis muscle changes in clinically diagnosed PS patients by US and MRI and explore the value of imaging examinations for the diagnosis of PS.

METHODS

This was a cross-sectional study. Ethics approval was granted by the institutional clinical research ethics committee of Qianfoshan Hospital. We collected written consent from all subjects before the examinations. From March 1, 2015 to February 28, 2017, we enrolled patients from the Qianfoshan Hospital with complaints of chronic pain in their buttocks, thighs, and lower limbs.

Inclusion Criteria. To be eligible, the patients had to be 20–80 years old and have no evidence of clinically significant lumbar disk herniation or lumbosacral radiculopathy on MRI. Inclusion criteria for the PS group were the presence of one or more positive PS physical examinations, whereas inclusion in the group of healthy volunteers required a normal physical examination for PS.

Physical Examination. PS was defined by the following criteria reported previously²¹: (1) tenderness upon palpation of the greater sciatic notch or piriformis muscle line over the upper edge of the piriformis muscle and stretching from the greater trochanter to the superior boundary of greater sciatic foramen; (2) a positive FAIR test (hip flexion–adduction–internal rotation maneuver test); (3) a positive Pace maneuver test; (4) a positive Beatty maneuver test (buttock pain when the leg was flexed and elevated while the patients were lying on their asymptomatic side); and (5) a positive Freiberg maneuver test.

Exclusion Criteria. None of the patients had a previous surgical history involving the lumbar and/or hip region, abdominal cavity tumors, anatomic variations of the sciatic nerve by MRI, a body mass index (BMI) of greater than 35 kg/m², an autoimmune disorder for which they were being treated, clinically significant active or past disorders of the central or peripheral nervous system, a history of buttock or hip infection, active

Additional supporting information may be found in the online version of this article.

Abbreviations: AUROC, area under the receiver operating characteristic curve; BMI, body mass index; CSA, cross-sectional area; CT, computed tomography; EMG, electromyography; ICC, intraclass correlation coefficient; iCSA, increased CSA (%); iTh, increased thickness (%); PS, piriformis muscle syndrome; ROC, receiver operating characteristic; TE, echo delay time; TR, repetition time; US, ultrasound

Key words: cross-sectional area; muscle thickness; piriformis muscle; piriformis muscle syndrome; ultrasound

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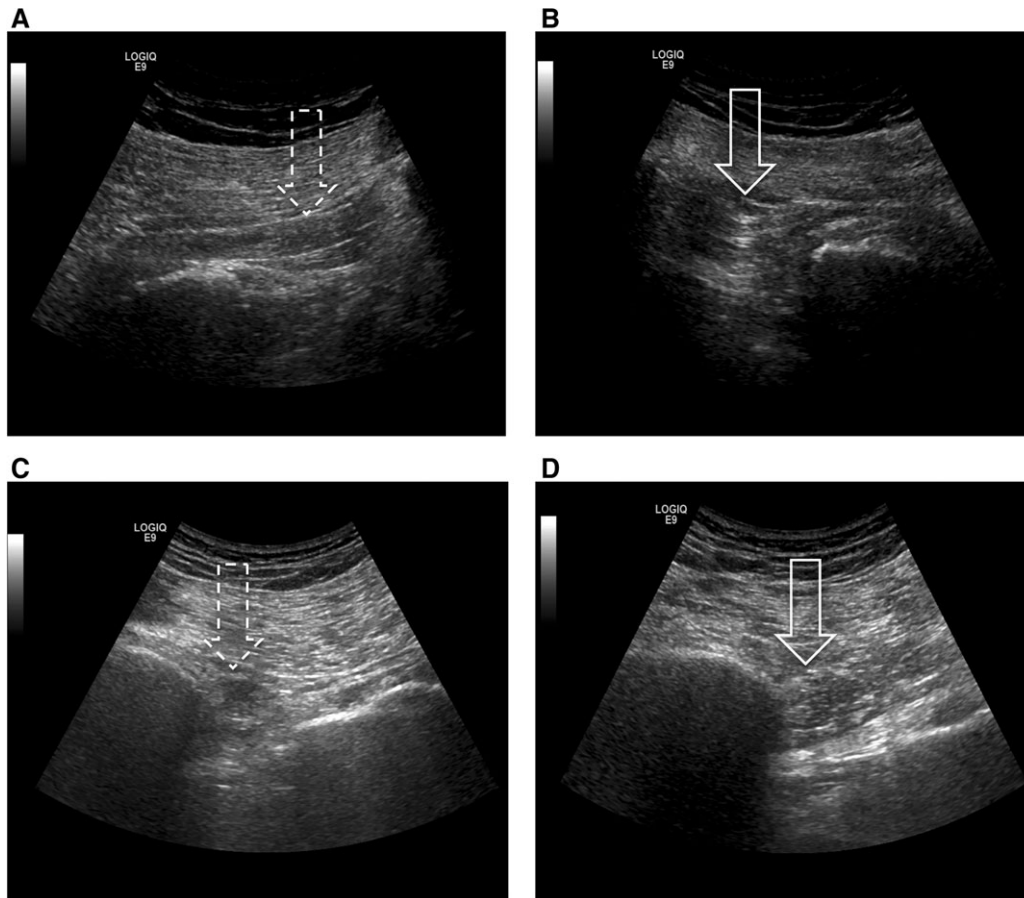


FIGURE 1. US images of the piriformis muscle. The piriformis muscle is located deep to the gluteus maximus muscle. The dotted arrow in (A) and (C) shows the asymptomatic piriformis muscle; the solid arrow in (B) shows a thicker piriformis muscle compared with the asymptomatic side; and the solid arrow in (D) shows a larger symptomatic piriformis muscle in piriformis muscle syndrome.

psychiatric diseases, vascular disease, malignancy, or diabetic neuropathy. MRI examination of the lumbar spine, pelvis, hips, and sacroiliac joint were used to rule out other causes of sciatica.

Clinical Scoring System. All patients underwent the procedures described previously by Michel *et al.*⁷ Examinations were performed bilaterally including clinical examination of the joints (i.e., spine, coxofemoral, sacroiliac), and neurological examination to detect any sensorimotor deficits or reflex abnormalities, the FAIR maneuver, the Freiberg maneuver, heel–contralateral knee maneuver for stretching the piriformis muscle, and the Beatty test for resisted contraction were assessed. After each maneuver, it was noted whether or not the patient experienced the triggering of pain.

Our study modified the Michel scoring system as follows:^{7,9,22,23} score <6 (group 0); score ≥6 and <8 (group 1); score ≥8 and <11 (group 2); and score ≥11 and <12 (group 3).

US and MRI examinations of the piriformis muscle were performed bilaterally.

Ultrasound. Ultrasound was performed using a curvilinear transducer (C1–5) (LOGIQ E9 System; GE Healthcare). One sonographer, with more than 10 years of experience in musculoskeletal US, completed all of the US examinations. The gluteus maximus muscle was chosen for echo-intensity analysis for comparison. The thickness of the piriformis muscle in the longitudinal plane and muscle cross-sectional areas (CSAs) were measured bilaterally (Fig. 1, Fig. S1a and b in

Supplementary Material online, and Fig. 2). The thickness and CSA for each muscle were measured 10 times to reduce variation. Moreover, the echo-intensity changes in piriformis muscle and surrounding tissue were also evaluated.

MRI Examination. The MRI scans of the piriformis muscle were acquired using a 3-T MR scanner (Magnetom Skyra; Siemens Healthcare, Erlangen, Germany).

ImageJ version 1.50q (NIH, Bethesda, Maryland) software was used for piriformis muscle measurement.²⁴ For CSA measurement in MR images, we first confirmed that the picture type was "8-bit," then we selected the straight tool (main toolbar straight line) to draw a line of the same length as the ruler in the photo. Finally, using a tracing method, "freehand selections" were used to determine the target boundary, analyze and output results. For US images, the echo intensity of piriformis muscle was also measured by ImageJ.

The muscle thickness and CSA were measured by manually outlining the piriformis muscle boundary on 3 consecutive axial slices from the point at which the muscle was first visible on the image. The average CSA and thickness of the 3 slices were determined for each side.

Statistical Analysis. Statistical analyses were performed using SPSS version 22 (IBM, Armonk, New York) software. Data with a normal distribution are presented as mean ± standard deviation; differences between groups were determined using a *t*-test. Demographic characteristics, including age and sex, were analyzed with

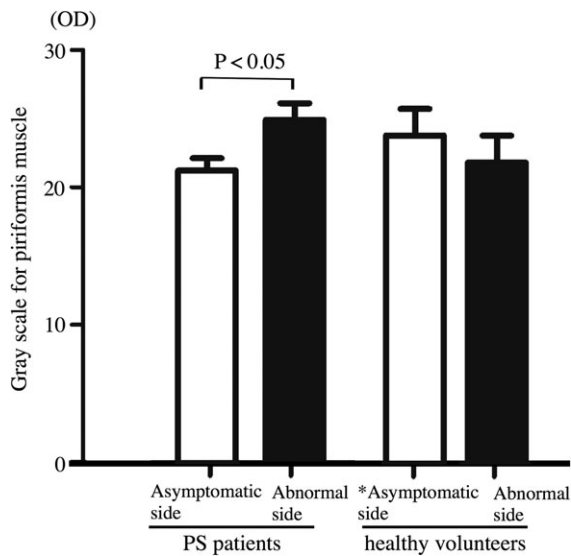


FIGURE 2. Echo intensity (gray scale) of the piriformis muscle in piriformis muscle syndrome (PS) patients and healthy volunteers. The gray-scale level increased in PS patients significantly, whereas there was no significant difference in the 2 sides of healthy volunteers. OD: optical density; black: abnormal side; white: asymptomatic side. *Asymptomatic side indicates the right side and abnormal side indicates the left side of piriformis muscle in healthy volunteers.

Student's *t* test for intergroup comparisons. *iTh* and *iCSA* were compared among the subgroups (stages 0, 1, 2, and 3) of clinically diagnosed PS patients using the Kruskal–Wallis test. The diagnostic performance of the significant US parameters was analyzed using receiver operating characteristic curves (ROCs). The results were considered significant at $P \leq 0.05$.

RESULTS

A total of 33 clinically diagnosed PS patients (mean age 45 years; 16 males) and 26 healthy volunteers (mean age 54 years; 15 males) were included. Demographic data are presented in Table 1. There were no significant differences in age, weight, height, BMI, or gender ratio between patients and healthy volunteers.

Clinical presentations and physical examinations were significantly different between patients with PS and healthy volunteers (Table 1). Clinical assessment scores are shown in Table 2.

The intrarater reliability of CSA measurements by intraclass correlation coefficient (ICC) were high (left ICC1, $1 = 0.90$; right ICC1, $1 = 0.99$). Comparative studies of the imaging parameters for PS patients and healthy volunteers (Table 3) revealed significant differences in piriformis muscle thickness (Fig. S1a and b), with the symptomatic piriformis muscle being thicker than the muscle on the asymptomatic side in PS patients. CSA demonstrated a significant difference between the symptomatic side and asymptomatic side in PS patients (Fig. S1b and d, and Table 3). Neither muscle thickness nor CSA was significantly different between 2 sides of healthy volunteers. In addition,

25 patients exhibited increased echo intensity of the epimysium and surrounding adipose tissue, and 16 patients exhibited a visible increase in piriformis muscle echo intensity compared with that on asymptomatic side.

MRI. Twenty-eight of the 33 PS patients underwent MRI examination, whereas 5 could not undergo MRI due to metal implants. The images showed enlarged piriformis muscles on the symptomatic side in PS patients (see Fig. S2a online), and the thickness and CSA exhibited significant differences between the symptomatic and asymptomatic sides in PS patients (Table 3). An increase in signal intensity on T2-weighted MRIs was found in all PS patients (see Fig. S2b online). The muscle thickness, CSA, and signal intensity exhibited no significant differences between the 2 sides among healthy volunteers.

US Parameters (*iTh* and *iCSA*). The US parameters (i.e., the *iTh* and *iCSA* of the piriformis muscle) for the different clinically diagnosed PS scoring stages are presented in Table 4. Significant differences were found for *iTh* and *iCSA* among the clinically diagnosed PS scoring stages.

The gray-scale value was significantly increased in symptomatic piriformis muscles compared with asymptomatic sides in PS patients, whereas no significant difference was found in healthy volunteers (Fig. S2).

Although there were no significant differences between the normal (stage 0) group and stage

Table 1. Demographics of piriformis syndrome patients compared with healthy volunteers.

	PS patients	Healthy volunteers	<i>P</i> -value
Age (years)	45.4 ± 13.6	53.7 ± 16.9	0.051
Sex (male/female)	16/17	15/11	0.189
Body mass index	23.8 ± 2.87	24.2 ± 1.01	0.278
Weight (kg)	66.3 ± 1.34	67.7 ± 1.05	0.412
Height (cm)	167.0 ± 6.32	167.1 ± 6.17	0.977
Clinical presentation		0	
Walking pain	7 (21.2%)	0	<0.01
Sitting pain (inability to sit for >30 minutes)	31 (93.9%)	0	<0.01
Radicular pain	7 (21.2%)	0	<0.01
Paresthesia	20 (60.6%)	0	<0.01
			>0.05
Physical examination			
Tenderness	22 (66.7%)	0	<0.01
FAIR test	16 (48.5%)	0	<0.01
Pace sign	9 (27.3%)	0	<0.01
Beatty test	4 (12.1%)	0	<0.01
Seated piriformis test	28 (84.8%)	0	<0.01
US changes			
Surrounding tissue change	25 (75.8%)	0	<0.01
Muscle echo intensity enhancement	16 (48.5%)	0	<0.01

Data expressed mean ± SD or as number (%).

PS, piriformis syndrome; US, ultrasound; SD, standard deviation.

Table 2. Scoring results for the bilateral assessment of piriformis syndrome in patients and healthy volunteers.

Scoring	Clinical group	PS patients		Healthy volunteers	
		Asymptomatic side	Abnormal side	Right side	Left side
Score <6	Stage 0	33	0	26	26
Score ≥6, <8	Stage 1	0	2	0	0
Score ≥8, <11	Stage 2	0	22	0	0
Score ≥11, ≤12	Stage 3	0	9	0	0
Total		33	33	26	26

PS, piriformis syndrome.

Table 3. Mean and standard errors of the piriformis muscle thickness and cross-sectional area for piriformis syndrome patients compared with healthy volunteers.

	Thickness (cm)		CSA (cm ²)	
	Asymptomatic side*	Abnormal side	Asymptomatic side	Abnormal side
US				
PS patients	1.20 ± 0.22	1.41 ± 0.21 [†]	3.50 ± 0.75	4.10 ± 0.82 [†]
Healthy volunteers	1.31 ± 0.17	1.30 ± 0.14	3.82 ± 0.40	3.80 ± 0.44
MRI				
PS patients	1.76 ± 0.25	2.06 ± 0.32 [‡]	7.10 ± 2.31	8.23 ± 3.04 [‡]
Healthy volunteers	1.53 ± 0.44	1.70 ± 0.46	7.48 ± 2.69	7.43 ± 2.13

CSA, cross-sectional area; MRI, magnetic resonance imaging; US, ultrasound.

*Asymptomatic side indicates the right side and abnormal side indicates the center side in the muscle thickness and CSA examinations of healthy volunteers.

[†] $P < 0.05$ compared with the asymptomatic side in the PS patients by US.

[‡] $P < 0.05$ compared with the asymptomatic side in the PS patients by MRI.

1 group in iTh, the normal group had a significantly lower iTh than the stage 2 and 3 groups, and the stage 2 group had a significantly lower iTh than the stage 3 group. The stage 0 group had a lower iCSA than the patient groups, and a significantly lower iCSA was found in the stage 1 group than in the stage 2 group, and in the stage 2 group than in the stage 3 group (Fig. 3).

ROC Analysis. ROC analyses were performed on iTh and iCSA to discriminate between stage 2 and stage 3 groups and between stage 0 and overall PS groups (stages 1–3). The areas under the ROC curve (AUROCs) for iTh and iCSA for discriminating between stage 2 and stage 3 groups were 0.82 and 0.89, respectively, whereas those for discriminating between stage 0 and stages 1–3 were 0.88 and 0.95, respectively (Fig. 4). The AUROCs for iCSA were higher than those for iTh with regard to discriminating between different stages.

DISCUSSION

Our study has demonstrated that, in PS patients, the piriformis muscles were enlarged and the echo intensity of this muscle was enhanced. Furthermore, the piriformis muscle thickness was significantly increased on the symptomatic side compared with that on the asymptomatic side.

As discussed earlier, there is currently no “gold standard” test for PS diagnosis. Based on the Michel clinical scoring system, iTh and iCSA are excellent parameters for differentiating between stage 2 and stage 3 PS and between normal and all-stage PS patients. Our results are similar to those of Siddiq *et al.*,^{19,20} who found that piriformis muscle thickness increased, but did not describe CSA.

Anatomically, because the piriformis muscle is pear-shaped, thickness assessment alone is not sufficient to evaluate changes. Felix reported an increased CSA of the piriformis muscle on MRI in elite football players.²⁴ We demonstrated that piriformis muscle CSA in PS patients was increased on the symptomatic

Table 4. US parameters (increased thickness and cross-sectional areas) in the different clinically diagnosed PS scoring stage groups.

US parameters (%)	Clinically diagnosed PS scoring stages			
	Stage 0 (n = 26)	Stage 1 (n = 2)	Stage 2 (n = 22)	Stage 3 (n = 9)
Increased thickness	1.11 ± 10.42	5.398 ± 1.205	16.32 ± 7.302	26.32 ± 8.130
Increased CSA	-0.38 ± 9.01	4.244 ± 0.0315	15.71 ± 5.180	24.61 ± 5.221

US, ultrasound; CSA, cross-sectional areas; PS, piriformis syndrome.

$P < 0.001$ for US parameters compared with PS scoring stage groups

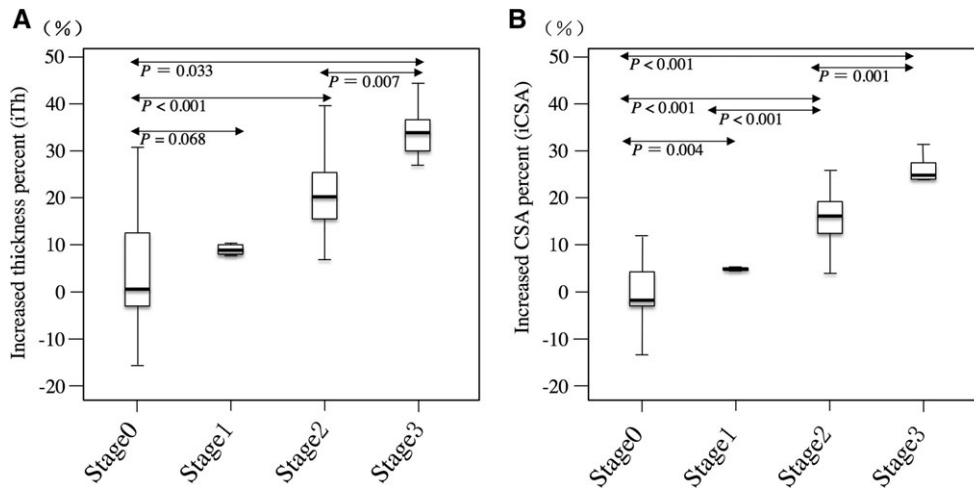


FIGURE 3. US parameter-increased thickness (iTh) and cross-sectional area (iCSA) of piriformis muscle in different clinically diagnosed piriformis muscle syndrome (PS) scoring stages. **(A)** iTh increased with the increasing PS scoring stages. **(B)** iCSA increased with the increasing PS scoring stages.

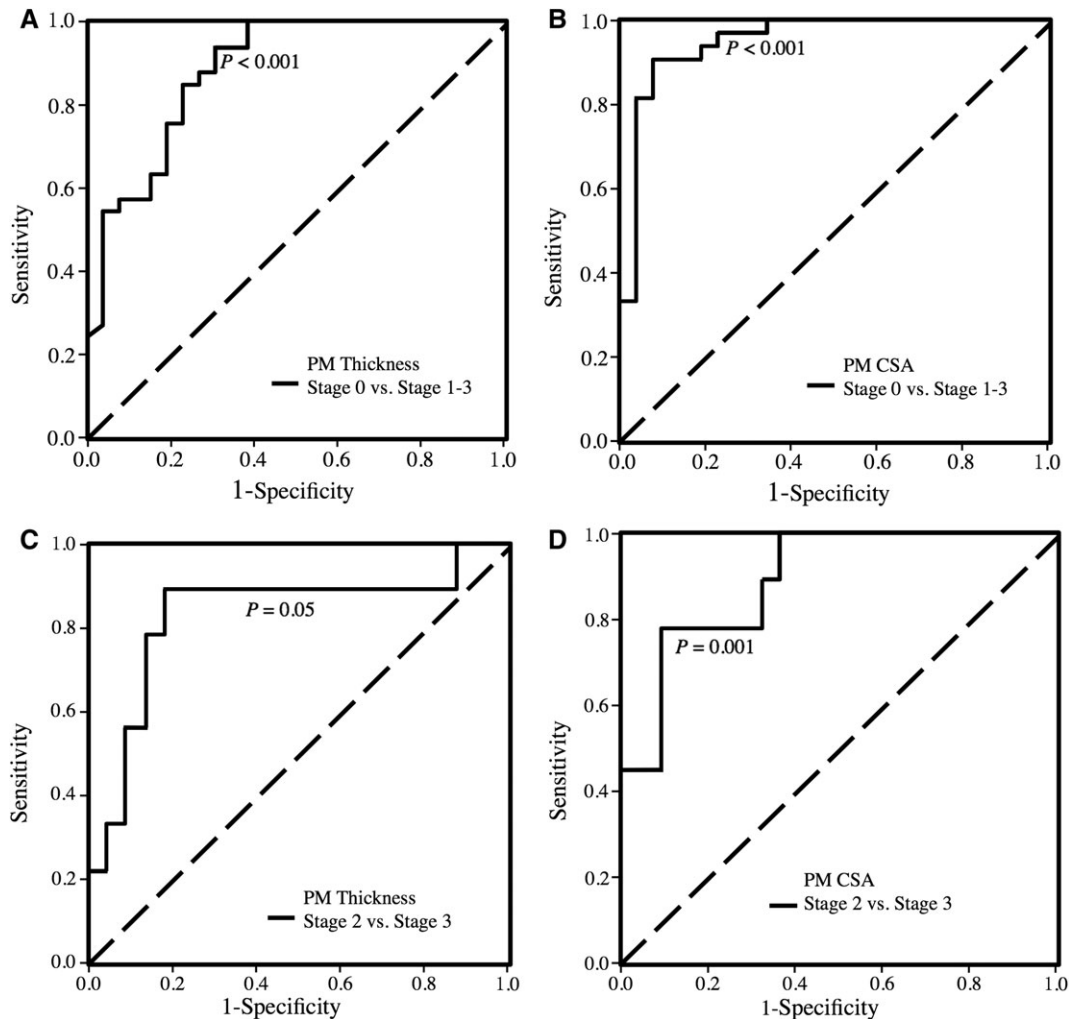


FIGURE 4. Receiver operating characteristic curve (ROC) analyses were performed in increased thickness (iTh) and cross-sectional area (iCSA). **(A)** The area under the ROC curves (AUROC) of iTh for discriminating stage 0 from stage 1, stage 2, and stage 3 groups were 0.88 (95% CI 0.80–0.97). **(B)** The AUROC of iCSA for discriminating stage 0 from stage 1, stage 2, and stage 3 groups was 0.95 (95% CI 0.89–1.00). **(C)** The AUROC of iTh for discriminating between stage 2 and stage 3 groups was 0.82 (95% CI 0.64–1.00). **(D)** The AUROC of iCSA for discriminating between stage 2 and stage 3 groups was 0.89 (95% CI 0.78–1.00).

side according to MRI and US. Moreover, we found that the CSA on MRI was larger than that seen on US. This difference may result from the fact that the piriformis muscle is oblique (Fig. S1a). The CSA based on MRI is not an anatomical cross-section of piriformis muscle; however, using US, the cross-section was acquired perpendicular to the longitudinal section of the piriformis muscle (Fig. S1c). Nonetheless, MRI is of limited applicability because of the longer imaging time, poor spatial resolution, and contraindication for patients with metal implants. Our study indicates that US assessment can conveniently provide measurements of CSA changes in piriformis muscle. Moreover, the sensitivity, specificity, and positive predictive values of iCSA and iTh are very high. Once validated, this tool could be used for the inclusion of patients in future PS studies to enable accurate monitoring of PS over time.

Although PS may only involve the piriformis muscle itself, in our study both the muscle and the surrounding tissue exhibited echoic and MRI changes in PS. To the best of our knowledge, the pathology of PS is not clear.^{7,22} Benson *et al.* reported spasms or enlargements of the piriformis muscle during surgery,²⁵ and Kanakis *et al.* concluded that the pathophysiology of PS includes single blunt trauma; overuse causing piriformis hypertrophy; and long-term microtrauma causing scarring, piriformis muscle inflammation, and fibrosis.²² In our study, the echoic changes found in the epimysium or adipose tissue may have been due to the spread of muscle inflammation to the surrounding area.

In addition, in PS patients who complained of sciatica, the sciatic nerve exhibited a coarse and blurred edge in this study. Some early case reports suggested that the sciatic nerve is compressed by hypertrophy or spasm of the piriformis muscle or is affected by inflammation and edema of this muscle.^{26,27}

Our study has limitations, including a relatively small number of patients, wide age range of patients, and the intrinsic limitation of the technique for ultrasonographic muscle assessment. Further studies with larger populations will be required to validate both our results and the reliability of US measurements of the piriformis muscle. Furthermore, our study did not include assessments of variations in the piriformis muscle and sciatic nerve. However, Fishman *et al.* suggested that anatomic variation is unlikely responsible for PS. Furthermore, anatomical abnormalities are almost invariably bilateral, whereas PS is 90% unilateral.¹⁰

In conclusion, US and MRI revealed similar muscle changes in PS patients. Our findings indicate that US may be a reliable and convenient technique for the diagnosis of PS.

Ethical Publication Statement: We (the authors) confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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