

Ultrasonographic Evaluation of the Distal Medial Hamstring Tendons and their Association with Posteromedial Knee Pain

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Abstract

Background: Periarticular abnormalities are common ultrasonographic (U/S) findings in individuals with knee pain. Incidental U/S observations, including thickening of the distal hamstring tendons, require explanations for their clinical importance. In addition, it is unclear whether or not these tendon modifications are related to knee pain. The objective is to determine U/S findings of distal medial hamstring tendons in patients with posteromedial (PM) knee pain and assess the diagnostic significance of tendon thickness in predicting tendinopathy in those patients. **Methods:** We studied the distal medial hamstring tendons (semimembranosus [SM] and semitendinosus [ST]) of 104 patients (104 knees) with nontraumatic unilateral PM knee pain and 118 healthy controls (236 knees). U/S evaluations included tendon thickness, echogenicity, the presence of intrasubstance tears, calcifications, and vascularity. **Results:** The mean age of patients and controls was 51.7 ± 10.4 years and 49.8 ± 9.9 years, respectively. The mean Visual Analog Scale (VAS) for pain among patients was 5.1, with 58.6% of them reporting pain at the medial joint line. The study patients had significantly higher mean SM and ST tendon thicknesses than the controls (7.17 mm vs. 5.46 mm and 3.93 mm vs. 3.45 mm, respectively). U/S abnormalities among patients were hypoechogenicity (62.5%), intrasubstance tears (31.7%), loss of fibrillar pattern (23.1%), baker cyst (20.2%), calcification (18.3%), anserine bursitis (11.5%), and neovascularization (6.7%). We found significant correlations between tendon thickness and VAS ($r = 0.752$, $P = 0.004$) as well as pain location ($r = 0.680$, $P = 0.008$). SM tendon thickness measured by U/S was more accurate in predicting tendinopathy than ST (80.6% vs. 68.9%). **Conclusion:** U/S changes tend to occur frequently in individuals experiencing PM knee pain. Among the various abnormalities detectable by U/S, an increase in tendon thickness serves as a reliable indicator of tendinopathy and correlates strongly with the location and severity of knee pain. When dealing with PM knee pain, a comprehensive evaluation of the distal medial hamstring tendons through U/S examination can be instrumental in achieving a timely and accurate diagnosis as well as an effective treatment plan.

Keywords: Hamstring tendons, knee pain, semimembranosus, semitendinosus, tendinopathy, ultrasonography

INTRODUCTION

Chronic tendon changes cause pain and dysfunction that interfere with both occupational and nonoccupational daily activities. Across all body sites, tendinopathy is seen in 2%–5% of cases. These variances are brought on by various diagnostic criteria, research areas, and populations.^[1] Despite being widespread in athletes, lower limb tendinopathy is also frequently observed in nonathletes.^[2] The distinction between medial hamstring tendinopathy and other causes of posteromedial (PM) knee pain is vital for pain management. To the best of our knowledge, there are currently no

investigations into the occurrence of hamstring tendinopathy among individuals with PM knee pain. Compared to clinical examination alone, ultrasonographic (U/S) findings can pinpoint the exact site and increase diagnostic accuracy.^[3] Hip extension and knee flexion throughout the gait cycle are the main functions of the hamstring. At the swing phase, it serves as a dynamic stabilizer of the anterior tibial translation, and

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at takeoff, it contracts with the quadriceps to push off from the supporting leg.^[4] Due to the fibrous nature and resistance of the tendon, tendon rupture is less common than tendinosis, a noninflammatory form of tendon deterioration. Tendon tendinosis, which typically develops at the most critical zone of least vascularity, may be brought on by tendon degeneration brought on by collagen degradation. These tendon changes include hypoxia, the accumulation of large mucous patches, and vacuolar degeneration.^[5] Other essential factors, such as the patient's age, recurrent damage, and tendon biomechanics, are crucial in determining the critical zone.^[6] This zone varies from tendon to tendon; for instance, it is located 8–15 mm from the rotator cuff tendon insertion and in the middle of the Achilles tendon.^[7] For the crucial zone of the distal medial hamstring tendon, no data is currently available. Tendon tenderness and swelling are the clinical signs of tendinosis. Tendinosis does not necessarily present with symptoms, though. Tendon thickening and hypoechoic swelling, loss of the normal fibrillary pattern, and neovascularization are some of the U/S findings of tendinosis. According to Robinson,^[8] pain is strongly correlated with tendon thickening, making tendon thickness a reliable predictor of tendinopathy and dysfunction.^[9] Hence, to assess the accuracy of tendon thickness measures in the diagnosis of tendinopathy, comprehensive research is required. We hypothesized that there would be significant differences in thickness measurements between the affected and healthy tendons. For this reason, we conducted the present study to assess the U/S changes of the distal medial hamstring tendons and their correlation with PM knee pain.

MATERIALS AND METHODS

Study participants and data collection

This study included 104 patients (26 males and 78 females) with nontraumatic unilateral PM chronic (>6 months) knee pain and 118 aged and sex-matched healthy volunteers (43 males and 75 females) with no history of musculoskeletal pain, injuries, or inflammation as the control group. We recruited the participants from the Armed Forces Rehabilitation Hospital in Taif City, Saudi Arabia, and the rheumatology outpatient clinic of Al-Azhar University Hospitals in Cairo, Egypt, from October 1, 2018, to February 28, 2020, and assessed their study eligibility. Patients with posttraumatic or postoperative distal hamstring tendonitis following knee replacement surgery, anterior cruciate ligament tears, and medial collateral ligament injuries were excluded from the study.

The Research Ethical Committee of Armed Forces Rehabilitation Hospitals, Taif City, Saudi Arabia, reviewed and accepted the study protocol with an approval code of 3342119. We prepared the study according to the principles expressed in the Helsinki Declaration.^[10] All participants provided informed written consent and understood the aim and the benefits of the study before any intervention. We followed the recommendations of the STROBE guidelines during the preparation of this manuscript.

Pain severity assessment

The Visual Analog Scale (VAS) was employed to rate the intensity of the pain. The VAS consists of a 10-cm long line, where 0 corresponds to no pain and 10 to severe pain. Patients indicated their level of discomfort on a line, and we collected VAS by calculating the length between zero and the mark.^[11] We defined mild pain as a VAS score below 3.4, moderate pain as one between 3.5 and 7.4, and severe pain as one over 7.5.^[12]

Ultrasonographic evaluation

All U/S examinations for patients and controls were carried out by a qualified, certified sonographer (H.S.) who is a member of the European League Against Rheumatism. Participants lay down comfortably in the prone position while the examiner marked the PM portion of the knee to direct the movement of the U/S transducer. By employing a 38.4 mm linear transducer (VF10-5), 4.0–11.4 MHz (Siemens, ACUSON P500TM ultrasound system), at 25% intervals of tendon length for semitendinosus (ST) (4 segments) and 50% intervals for semimembranosus (SM) (2 segments), we assessed the hamstring tendons using B-mode and power Doppler and determined the free tendon length from the muscle–tendon junction (MTJ) proximally to the site of insertion distally by measuring the tendon thickness at the midpoint of each segment.^[13] The sonographer visually reviewed the entire U/S image for the best quality (e.g., clarity and minimal anisotropy) and scanned each location three times for subsequent assessment. We used anisotropic images as a reference for tendon borders, and the images were acquired vertically along the tendon longitudinal axis.^[14]

U/S is considered an accurate, valid, and reliable method to diagnose tendinopathy.^[15] We used the U/S criteria for the identification of tendinopathy as described by Comin *et al.*^[16] The primary characteristics of tendinopathy were determined, including tendon thickness, hypoechoic changes in the tendon structure, and neovascularization, which refers to heightened vascularity in close proximity to the tendon, as well as any additional irregularities such as tendon intrasubstance tears, intratendinous calcifications, loss of fibrillar arrangement, Baker's cyst, and anserine bursitis. Figure 1 shows some of the pathological changes of the study participants. Figures 2 and 3 show the difference in tendon thickness between normal and diseased individuals.

Statistical analysis

We accomplished the statistical evaluation using Statistical Package for Social Sciences (SPSS), version 23.0 (IBM SPSS®, Statistics 23, Armonk, NY, USA). For quantitative data (such as age, body mass index [BMI], VAS, and tendon thicknesses), we estimated the means and standard deviations. To analyze the differences between the patient and control groups, we performed an independent *t*-test. We took note of how frequently U/S anomalies occur. To analyze the qualitative data (such as gender [male or female], knee side [right or left], pain severity [mild, moderate, or severe], pain location [superior medial, medial joint line, or inferior medial],

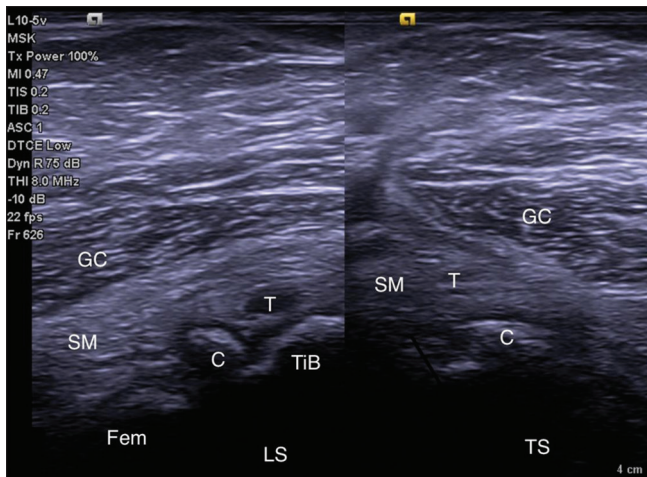


Figure 1: Longitudinal (LS) and transverse (TS) scans of the distal semimembranosus tendon showed intra-tendinous calcification. Femur, gastrocnemius muscle, tear, and tibia. SM: semimembranosus, GC: Gastrocnemius, C: Calcification, T: Tear, TIB: Tibia, LS: Longitudinal, TS: Transverse scans

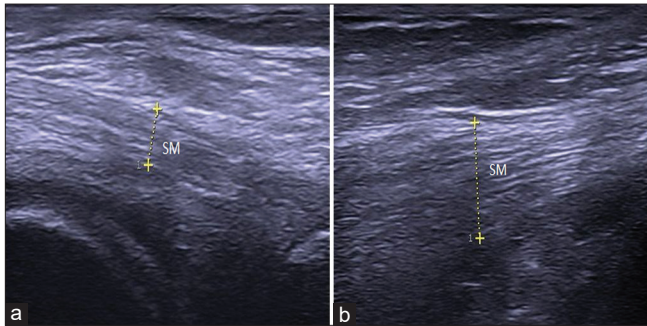


Figure 2: Longitudinal scan of the distal semimembranosus tendon in a normal individual (a) and with increased thickness in a diseased individual (b). SM: Semimembranosus tendon

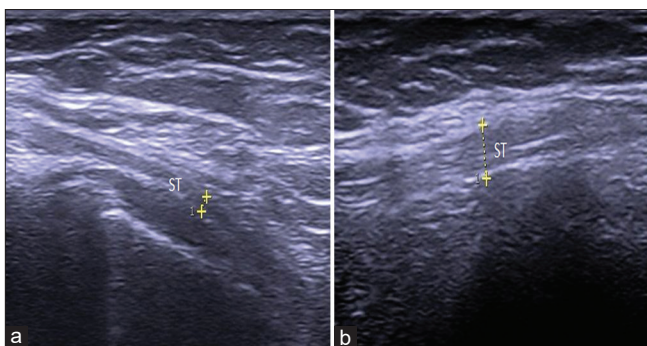


Figure 3: Longitudinal scan of the distal semitendinosus tendon in a normal individual (a) and with increased thickness in a diseased individual (b). ST: Semitendinosus tendon

and osteoarthritis [OA]), we conducted Chi-square or Fisher's exact tests. Receiver operating characteristic (ROC) analysis was used to establish a cutoff value for tendon thickness that would distinguish between tendinopathy's presence and absence. To determine the relationship between pain location and intensity, we calculated the correlation coefficient (r), with

$r = 0.3$ denoting an insignificant association, 0.3–0.5 denoting a low correlation, 0.5–0.7 denoting a moderate correlation, and >0.7 denoting a strong correlation.^[17] We set the $P \leq 0.05$ as the statistically significant level.

RESULTS

The mean age of the studied patients was 51.7 ± 10.4 years, while it was 49.8 ± 9.9 years in the control group. We matched both groups regarding age, gender, and BMI ($P > 0.05$). Out of 104 patients, 53.8% complained of the left knee pain, 60.6% suffered from moderate pain (mean VAS was 5.1 ± 1.2), and the pain was mostly located at the medial joint line (58.6%) [Table 1]. We diagnosed knee OA in 61.5% of the patients based on the American College of Rheumatology classification criteria for knee OA.^[18]

In terms of U/S findings, the tendon thickness of SM and ST differs significantly between groups at all tendon measurement sites. Our patients had significantly higher mean SM1 (distal tendon [DT]) tendon thickness (7.36 mm vs. 5.13 mm), SM2 (MTJ) tendon thickness (7.17 mm vs. 5.46 mm), and ST4 (MTJ) tendon thickness (3.93 mm vs. 3.45 mm) compared to controls ($P < 0.05$) [Table 2].

Furthermore, we found a significant difference between the patients and controls regarding other U/S findings, including hypoechogenicity (62.5% vs. 6.8%), intrasubstance tears (31.7% vs. 1.3%), loss of fibrillar pattern (23.1% vs. 0.0%), Baker's cyst (20.2% vs. 3.8%), intratendinous calcification (18.3% vs. 2.1%), anserine bursitis (11.5% vs. 0.8%), and neovascularization (6.7% vs. 0.0%) ($P < 0.001$) [Table 3].

As shown in Table 4, U/S tendon thickness at different scanning locations showed a highly significant correlation with pain severity ($r = 0.752$, $P = 0.004$) as determined by VAS. U/S tendon thickness was also correlated with medial joint line pain ($r = 0.680$, $P = 0.008$).

Furthermore, we discovered that the most affected tendon sites exhibiting the greatest U/S changes of the studied tendons were (in descending order) the MTJ of SM (68.3%), the DT of SM (60.6%), the MTJ of ST (39.4%), the DT of ST (29.8%), and the mid-portions of ST (26.9%) and (24.0%) [Table 5].

As shown in Table 6, multiple regression analysis shows that with each point increase in VAS of pain intensity, tendon thickness significantly increases by 0.237 mm ($P < 0.05$) after adjusting for age and gender. The examined side and the presence of OA did not affect the tendon thickness significantly ($P > 0.05$).

The ROC curve was used to establish cutoff values for measured tendon thickness at various sites to predict tendinopathy [Figure 4].

Furthermore, as shown in Table 7, at a cutoff level of SM tendon thickness >6.6 , the MTJ was the most accurate site (80.6%) in predicting tendinopathy (70.2% sensitivity, 89.8% specificity, and area under curve = 0.835), followed by the DT of SM and the MTJ of ST (accuracy of 78.8% and 68.9%, respectively).

Table 1: Demographic and clinical data of the studied groups

Variables	Patients (n=104), n (%)	Controls (n=118), n (%)	P
Age (years), mean±SD	51.7±10.4	49.8±9.9	0.16
Gender			
Male	26 (25.0)	43 (36.4)	0.09
Female	78 (75.0)	75 (63.6)	
Side			
Right knee	48 (46.2)	62 (52.5)	0.41
Left knee	56 (53.8)	56 (47.5)	
BMI (kg/m ²), mean±SD	30±13.3	29±6.3	0.50
VAS, mean±SD	5.1±1.2		
Pain severity			
Mild	41 (39.4)	-	-
Moderate	63 (60.6)		
Pain location			
Superior medial	8 (7.7)	-	-
Medial joint line	61 (58.6)		
Inferior medial	35 (33.7)		
Osteoarthritis			
Yes	64 (61.5)	-	-
No	40 (38.5)		

SD: Standard deviation, BMI: Body mass index, VAS: Visual Analog Scale

Table 2: Tendon thickness measurements at different sites

Variables	Patients (n=104)	Controls (n=236)	P
SM1 (DT)	7.36±1.96	5.13±1.25	0.001**
SM2 (MTJ)	7.17±1.59	5.46±0.86	0.001**
ST1 (DT)	2.14±0.73	1.91±0.62	0.02*
ST2 (midportion)	2.66±0.81	2.35±0.67	0.002*
ST3 (miportion)	3.32±0.92	3.08±0.41	0.015*
ST4 (MTJ)	3.93±0.63	3.45±0.68	0.001**

*Significant *P* value, **Highly Significant *P* value. Data presented as mean±SD. Measurements in mm. DT: Distal tendon, MTJ: Myotendinous junction, SM: Semimembranosus, ST: Semitendinosus

Table 3: Ultrasonographic findings of the distal medial hamstring tendons

Variables	Patients (n=104)	Controls (n=236)	P
Hypo echogenicity	65 (62.5)	16 (6.8)	0.001**
Intrasubstance tears	33 (31.7)	3 (1.3)	0.001**
Loss of fibrillar pattern	24 (23.1)	0	0.001**
Baker cyst	21 (20.2)	9 (3.8)	0.001**
Calcification	19 (18.3)	5 (2.1)	0.001**
Anserine bursitis	12 (11.5)	2 (0.8)	0.001**
Neovascularization	7 (6.7)	0	0.001**

**Highly significant *P* value. Data presented as n (%)

DISCUSSION

Distal SM tendinopathy (SMT) is a common cause of PM knee pain, yet it is often overlooked. It is an important entity

Table 4: Correlation between tendon thickness of semimembranosus and semitendinosus at different sites versus Visual Analog Scale and pain location

Variables	VAS		Pain location	
	<i>r</i>	<i>P</i>	<i>r</i>	<i>P</i>
SM1 (DT)	0.632	0.045*	0.652	0.030*
SM2 (MTJ)	0.752	0.004**	0.680	0.008**
ST1 (DT)	0.534	0.043*	0.552	0.040*
ST2 (midportion)	0.432	0.050*	0.352	0.047*
ST3 (midportion)	0.461	0.048*	0.452	0.050*
ST4 (MTJ)	0.585	0.040*	0.552	0.044*

*Significant *P* value, **Highly significant *P* value. DT: Distal tendon, MTJ: Myotendinous junction, SM: Semimembranosus, ST: Semitendinosus, VAS: Visual Analog Scale

Table 5: Frequency of the ultrasonographic changes at different tendon sites

Variables	Patients (n=104)
SM1 (DT)	63 (60.6)
SM2 (MTJ)	71 (68.3)
ST1 (DT)	31 (29.8)
ST2 (midportion)	25 (24.0)
ST3 (midportion)	28 (26.9)
ST4 (MTJ)	41 (39.4)

Data presented as n (%). DT: Distal tendon, MTJ: Myotendinous junction, SM: Semimembranosus, ST: Semitendinosus

Table 6: Multiple regression analysis for predictors of tendon thickness

Model	Unstandardized coefficients		<i>t</i>	Significant	95% CI for <i>B</i>	
	<i>B</i>	SE			Lower bound	Upper bound
Constant	5.457	0.773	7.060	0.000	3.923	6.990
Side	0.117	0.312	0.376	0.708	-0.501	0.736
VAS	0.237	0.092	2.571	0.012*	0.054	0.420
OA	0.549	0.317	1.733	0.086	-0.080	1.179

*Significant *P* value. VAS: Visual Analog Scale, SE: Standard error, CI: Confidence interval, OA: Osteoarthritis

to consider in people with PM knee pain, especially active adults, even though it is less frequent than other causes of pain such as meniscal tears or OA. It can be difficult to pinpoint the specific location of SMT. Typically, we base a diagnosis on a careful clinical evaluation. Imaging is frequently used to support a diagnosis and rule out alternative knee pain reasons. In general, we must rule out any further local sources of pain, such as calf muscle tears, intraarticular cartilage injury, and Baker's cyst.^[19] In general, tendinopathy, detected by U/S, is a continuum of pathological changes that include thickening and focal changes.^[20] Thickening represents a "prepathological" reactive state of ground substance deposition, and focal changes denote a consequent degenerative state of tissue apoptosis.^[21] Thickening predicts the development of focal

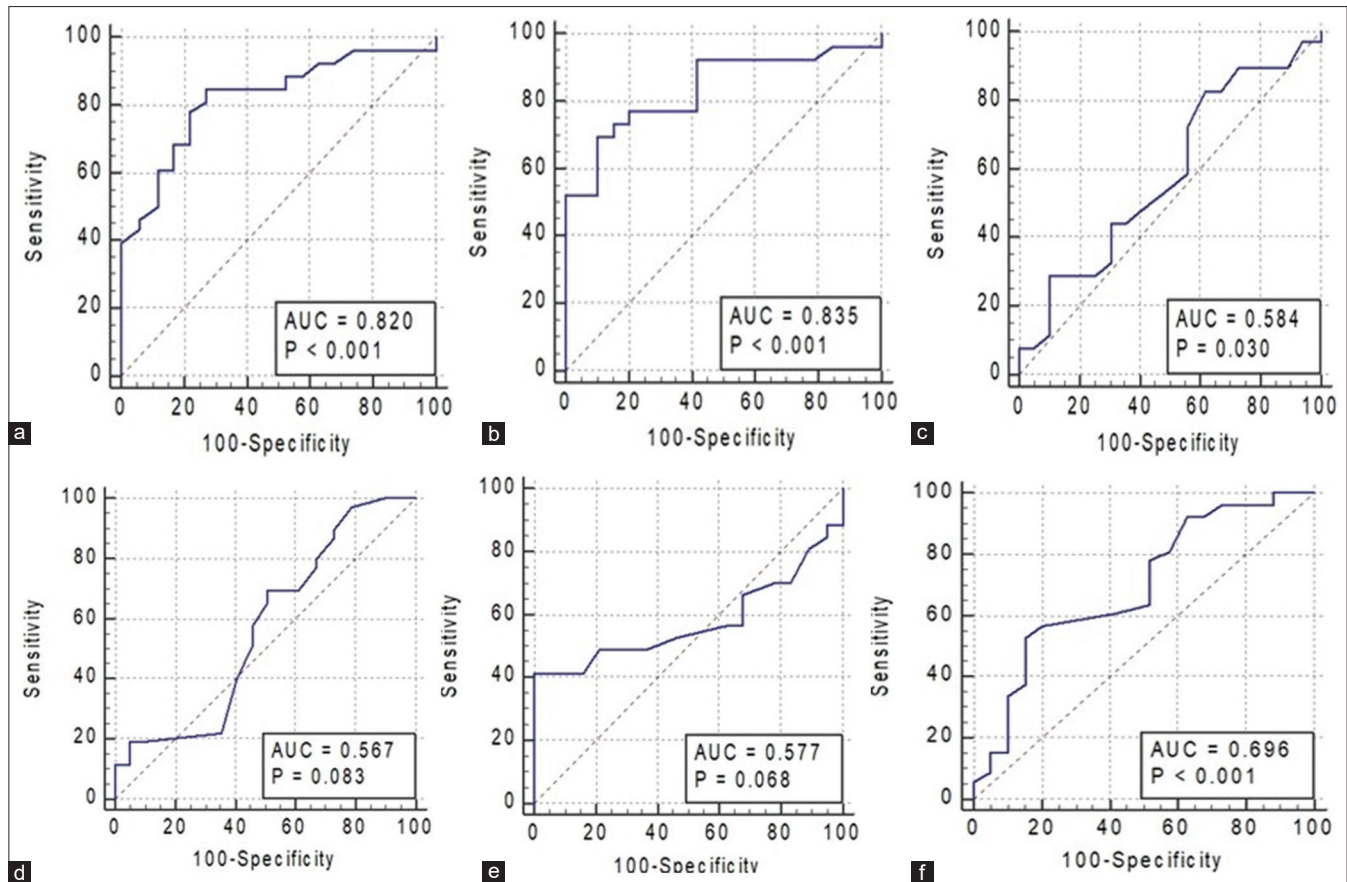


Figure 4: The receiver operating characteristic (ROC) curve for tendon thickness values in predicting tendinopathy. (a and b) The ROC of semimembranosus tendon thickness at different sites in predicting tendinopathy: (a) At the distal tendon (DT) and (b) At the myotendinous junction (MTJ). (c-f) The ROC of semitendinosus tendon thickness at various sites in predicting tendinopathy: (c) At DT, (d-e) at midportion, and (f) at MTJ. AUC: Area under curve

Table 7: Diagnostic values of tendon thickness in predicting tendinopathy

Tendons	Cutoff	Sensitivity	Specificity	+PV	−PV	Accuracy	AUC
SM1 (DT)	>5.3	84.6	72.9	73.3	84.3	78.8	0.820
SM2 (MTJ)	>6.6	70.2	89.8	85.7	76.8	80.6	0.835
ST1 (DT)	>1.6	69.1	44.1	53.2	64.2	57.7	0.584
ST2 (midportion)	>2.3	69.2	49.2	54.5	64.4	59.3	0.567
ST3 (midportion)	>3.3	49.0	68.6	58.0	60.4	59.0	0.577
ST4 (MTJ)	>3.7	56.7	79.6	71.1	67.6	68.9	0.696

SM: Semimembranosus, ST: Semitendinosus, +PV: Positive predictive value, −PV: Negative predictive value, AUC: Area under curve, DT: Distal tendon, MTJ : Myotendinous junction

hypochoic areas in previously normal tendons or returns them to normal in previously abnormal tendons.^[22]

Our results showed a high prevalence of U/S findings that include tendon thickening, intrasubstance tear, intratendinous calcification, hypoechogenicity, increased vascularity, and focal abnormalities. These findings were in concordance with previous studies.^[23-29]

To the best of our knowledge, this study is the first to reveal the prevalence of U/S findings of distal medial hamstring tendons. The medical literature did not spotlight hamstring tendinopathy, mostly because of physicians' insufficient

knowledge of this dysfunction. In addition, the PM corner of the knee is frequently neglected during diagnostic imaging.^[30] Early diagnosis of tendon dysfunction by careful history, detailed examination, and U/S studies in select cases perfectly results in successful management of associated underlying pathology.^[14]

Of the majority of our patients with SMT, 68.3% of them had U/S abnormalities at MTJ, and 60.6% had abnormalities at DT. Yoon *et al.*^[31] found similar findings during the U/S assessment of SM tendons, including abnormal thickening and signal alteration. The tendon of SM is more affected than ST because it is directly lying over the joint capsule, medial

femoral condyle, and medial tibial plateau, which may contain osteophytes, while that of ST passes superficially to SM, making it less liable to friction and shearing forces.^[14]

Our observations highlighted that tendon thickness was significantly correlated with the severity of knee pain. Likewise, Sánchez Romero *et al.*^[32] noticed that tendon thickness is correlated with pain, so it is considered an indirect measure of treatment outcome. Many other authors reported the same findings.^[9,33] These considerations highlight the importance of U/S as a fundamental tool to assist the clinician in the diagnosis of lower limb tendinopathies through the evaluation of the different parameters of tendon structure. Moreover, once tendon-related pain has developed, U/S can effectively guide management.^[32]

In the current study, the vascular changes were only found in 6.7% of our patients, and this may be due to the fact that we excluded those with histories of trauma or inflammatory diseases, so the tendon findings could be attributed mainly to the degenerative changes that lead to tendinosis rather than tendinitis. In addition, we found significant differences in the incidence of pes anserine bursitis and Baker's cyst between the two groups ($P < 0.05$). These findings suggest that these changes could also be related to the underlying OA degenerative changes.^[18]

CONCLUSION

Musculoskeletal ultrasound serves as a reliable and cost-efficient imaging technique for evaluating knee pain. Utilizing ultrasound-based assessments for the SM and ST tendons has proven effective in the detection of hamstring tendinopathy, with a direct correlation to the location and intensity of the knee pain. A focused examination of the distal medial hamstring tendons through ultrasound evaluation in individuals experiencing PM knee pain can facilitate prompt and precise diagnosis and management.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Abat F, Alfredson H, Cucchiari M, Madry H, Marmotti A, Mouton C, *et al.* Current trends in tendinopathy: Consensus of the ESSKA basic science committee. Part I: Biology, biomechanics, anatomy and an exercise-based approach. *J Exp Orthop* 2017;4:18.
- Albers IS, Zwerver J, Dierckx RL, Dekker JH, Van den Akker-Scheek I. Incidence and prevalence of lower extremity tendinopathy in a Dutch general practice population: A cross sectional study. *BMC Musculoskelet Disord* 2016;17:16.
- Rubin DA. Imaging diagnosis and prognostication of hamstring injuries. *AJR Am J Roentgenol* 2012;199:525-33.
- Rodgers CD, Raja A. Anatomy, Bony Pelvis and Lower Limb, Hamstring Muscle. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
- Thomopoulos S, Parks WC, Rifkin DB, Derwin KA. Mechanisms of tendon injury and repair. *J Orthop Res* 2015;33:832-9.

- Wang JH, Guo Q, Li B. Tendon biomechanics and mechanobiology – A minireview of basic concepts and recent advancements. *J Hand Ther* 2012;25:133-40.
- Chiavarras MM, Jacobson JA. Ultrasound-guided tendon fenestration. *Semin Musculoskelet Radiol* 2013;17:85-90.
- Robinson P. Sonography of common tendon injuries. *AJR Am J Roentgenol* 2009;193:607-18.
- Del Baño-Aledo ME, Martínez-Payá JJ, Ríos-Díaz J, Mejías-Suárez S, Serrano-Carmona S, de Groot-Ferrando A. Ultrasound measures of tendon thickness: Intra-rater, inter-rater and inter-machine reliability. *Muscles Ligaments Tendons J* 2017;7:192-9.
- World Medical Association. World Medical Association Declaration of Helsinki: Ethical principles for medical research involving human subjects. *JAMA* 2013;310:2191-4.
- Jensen MP, Chen C, Brugger AM. Interpretation of visual analog scale ratings and change scores: A reanalysis of two clinical trials of postoperative pain. *J Pain* 2003;4:407-14.
- Boonstra AM, Schiphorst Preuper HR, Balk GA, Stewart RE. Cut-off points for mild, moderate, and severe pain on the visual analogue scale for pain in patients with chronic musculoskeletal pain. *Pain* 2014;155:2545-50.
- van der Made AD, Wieldraaijer T, Kerkhoffs GM, Kleipool RP, Engebretsen L, van Dijk CN, *et al.* The hamstring muscle complex. *Knee Surg Sports Traumatol Arthrosc* 2015;23:2115-22.
- Kositsky A, Gonçalves BA, Stenroth L, Barrett RS, Diamond LE, Saxby DJ. Reliability and validity of ultrasonography for measurement of hamstring muscle and tendon cross-sectional area. *Ultrasound Med Biol* 2020;46:55-63.
- Matthews W, Ellis R, Furness J, Hing W. Classification of tendon matrix change using ultrasound imaging: A systematic review and meta-analysis. *Ultrasound Med Biol* 2018;44:2059-80.
- Comin J, Cook JL, Malliaras P, McCormack M, Calleja M, Clarke A, *et al.* The prevalence and clinical significance of sonographic tendon abnormalities in asymptomatic ballet dancers: A 24-month longitudinal study. *Br J Sports Med* 2013;47:89-92.
- Mukaka MM. Statistics corner: A guide to appropriate use of correlation coefficient in medical research. *Malawi Med J* 2012;24:69-71.
- Altman R, Asch E, Bloch D, Bole G, Borenstein D, Brandt K, *et al.* Development of criteria for the classification and reporting of osteoarthritis. Classification of osteoarthritis of the knee. Diagnostic and therapeutic criteria committee of the American Rheumatism Association. *Arthritis Rheum* 1986;29:1039-49.
- Sederberg M, LaMarche L, Skinner L, Cushman DM. Distal semimembranosus tendinopathy: A narrative review. *PM R* 2022;14:1010-7.
- Cook JL, Rio E, Purdam CR, Docking SI. Revisiting the continuum model of tendon pathology: What is its merit in clinical practice and research? *Br J Sports Med* 2016;50:1187-91.
- McCreesh K, Lewis J. Continuum model of tendon pathology – Where are we now? *Int J Exp Pathol* 2013;94:242-7.
- Docking SI, Ooi CC, Connell D. Tendinopathy: Is imaging telling us the entire story? *J Orthop Sports Phys Ther* 2015;45:842-52.
- Jhingan S, Perry M, O'Driscoll G, Lewin C, Teatino R, Malliaras P, *et al.* Thicker Achilles tendons are a risk factor to develop Achilles tendinopathy in elite professional soccer players. *Muscles Ligaments Tendons J* 2011;1:51-6.
- Giombini A, Dragoni S, Di Cesare A, Di Cesare M, Del Buono A, Maffulli N. Asymptomatic Achilles, patellar, and quadriceps tendinopathy: A longitudinal clinical and ultrasonographic study in elite fencers. *Scand J Med Sci Sports* 2013;23:311-6.
- Boesen AP, Boesen MI, Torp-Pedersen S, Christensen R, Boesen L, Hölmich P, *et al.* Associations between abnormal ultrasound color Doppler measures and tendon pain symptoms in badminton players during a season: A prospective cohort study. *Am J Sports Med* 2012;40:548-55.
- Ooi CC, Malliaras P, Schneider ME, Connell DA. Soft, hard, or just right? Applications and limitations of axial-strain sonoelastography and

- shear-wave elastography in the assessment of tendon injuries. *Skeletal Radiol* 2014;43:1-12.
27. de Jonge S, de Vos RJ, Van Schie HT, Verhaar JA, Weir A, Tol JL. One-year follow-up of a randomised controlled trial on added splinting to eccentric exercises in chronic midportion Achilles tendinopathy. *Br J Sports Med* 2010;44:673-7.
 28. Malliaras P, Purdam C, Maffulli N, Cook J. Temporal sequence of greyscale ultrasound changes and their relationship with neovascularity and pain in the patellar tendon. *Br J Sports Med* 2010;44:944-7.
 29. Matthews W, Ellis R, Furness JW, Rathbone E, Hing W. Staging Achilles tendinopathy using ultrasound imaging: The development and investigation of a new ultrasound imaging criteria based on the continuum model of tendon pathology. *BMJ Open Sport Exerc Med* 2020;6:e000699.
 30. Lundquist RB, Matcuk GR Jr., Schein AJ, Skalski MR, White EA, Forrester DM, *et al.* Posteromedial corner of the knee: The neglected corner. *Radiographics* 2015;35:1123-37.
 31. Yoon MA, Choi JY, Lim HK, Yoo HJ, Hong SH, Choi JA, *et al.* High prevalence of abnormal MR findings of the distal semimembranosus tendon: Contributing factors based on demographic, radiographic, and MR features. *AJR Am J Roentgenol* 2014;202:1087-93.
 32. Sánchez Romero EA, Pollet J, Martín Pérez S, Alonso Pérez JL, Muñoz Fernández AC, Pedersini P, *et al.* Lower limb tendinopathy tissue changes assessed through ultrasound: A narrative review. *Medicina (Kaunas)* 2020;56:378.
 33. McAuliffe S, McCreesh K, Culloty F, Purtill H, O'Sullivan K. Can ultrasound imaging predict the development of Achilles and patellar tendinopathy? A systematic review and meta-analysis. *Br J Sports Med* 2016;50:1516-23.