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ORIGINAL RESEARCH

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Hypoechoic ultrasonographic findings in the patellar ligaments are common in riding and trotting horses in training (116 cases)

Ellen Law[1] | Linda Wright[2] | Margareta Uhlhorn[1] | Elin Hernlund[2] | Carolina Nilemo[1] | Marie Rhodin[2]

[1]Diagnostic Imaging Clinic, University Animal Hospital, Uppsala, Sweden

[2]Department of Animal Biosciences, Swedish University of Agricultural Sciences, Uppsala, Sweden

Correspondence
Ellen Law, Diagnostic Imaging Clinic, University Animal Hospital, P.O. Box 7040, 750 07 Uppsala, Sweden.
Email: ellen.law@slu.se

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Abstract

Patellar ligament (PL) injuries are increasingly being reported in horses, but few studies have described the normal PL ultrasonographic appearance in horses. The aims of this prospective observational study were to describe the ultrasonographic appearance of the PLs and infrapatellar fat pad in a population of horses in training and to relate the ultrasonographic findings to objectively measured movement asymmetry. B-mode and color Doppler ultrasonographic examination of the PLs and infrapatellar fat pad in both hind limbs and objective gait analyses were performed on the 116 riding and trotting horses included in the study. The association between ultrasonographic findings, horse age, and movement asymmetry during the trot was then investigated.

Distinct or diffuse hypoechoic regions were commonly found in the intermediate PL (24/116; 20.7%), especially in the caudal aspect of the mid-third of the ligament. The infrapatellar fat pad had a hypoechoic striated appearance in all horses except one, in which it was hyperechoic. No association was found between ultrasonographic findings in the PLs and infrapatellar fat pad and lameness. It is important to recognize that there is biological variation in PL appearance, which may or may not be associated with pain in this area, therefore emphasizing the use of local analgesia to determine the location of the lameness.

KEYWORDS
jumper's knee, lameness, objective gait analysis, orthopedics, stifle, ultrasound

1 | INTRODUCTION

Pain and pathology originating from the stifle are important causes of hindlimb lameness in the horse.[1] Patellar ligament (PL) injuries are increasingly being recognized in horses,[2] but only a limited number of studies describe diagnosis, treatment, and prognosis for such injuries.[3,4,5]

In human recreational and professional athletes performing jumping sports, patellar tendinopathy (also known as "jumper's knee") is a common orthopedic complaint,[6,7] with the patient experiencing pain just below the patella.[8] Degenerative changes, including pathological neovascularization and perivascular nerve ingrowth in the patellar tendon, are now believed to be the origin of pain,[9] not the inflammatory state (desmitis) of the PL as initially suggested.[6]

Ultrasonography with color or power Doppler can be useful for the assessment of the jumper's knee.[10] The Doppler technique can detect and monitor increased blood flow in musculoskeletal tissue,[10,11] which is interpreted as a sign of pathology in human patients with clinical signs of tendinopathy.[12] A highly significant correlation between increased power Doppler signal and histopathological findings supports the value of this imaging technique.[13]

Ultrasonography of the equine stifle was first described in 1990[14], and it is now widely used as an important tool for diagnosing injuries in this complex joint.[15,16] However, only a few studies have examined the normal and abnormal appearance of the PLs in horses. The normal ultrasonographic appearance of the PLs in 10 clinically sound horses was described by Dyson.[5] In earlier studies[5,14] and more recent literature,[2,3,4] the PLs are reported to be homogeneously echogenic on ultrasonography, except in the most distal aspect of the intermediate patellar ligament (IPL), and in the lateral patellar ligament (LPL), where hypoechoic areas are commonly seen.

Patellar ligament injuries in horses have been identified ultrasonographically as core lesions, similar in appearance to core lesions of the superficial digital flexor tendon,[2] or more recently as linear lesions (tears).[3] However, color or power Doppler was not used in those studies to evaluate neovascularization, despite this being a common finding in patellar tendinosis in humans and in chronic flexor tendinopathies and suspensory ligament desmopathies in horses.[17,18]

The infrapatellar fat pad (IFP) is oval and is located between the PL and the femoropatellar joint capsule, enclosing the IPL. In humans, the IFP is a potent source of pain because of its rich innervation and close relationship with the highly innervated synovium.[19,20] IFP syndrome, also known as Hoffa's disease, is a relatively common condition in human athletes caused by inflammation of, local hemorrhage of, or insufficient space for the IFP.[19] To date, no corresponding pathology in horses has been described.

The aims of this study were thus to

1. Describe the ultrasonographic appearance of the patellar apparatus (PLs and IFP) in B-mode and color Doppler ultrasonography in horses in training.
2. Relate the ultrasonographic findings to movement asymmetry in objective gait analysis as a proxy for lameness.

2 | MATERIALS AND METHODS

2.1 | Study design

A prospective observational study was performed, in which horses were included if they fulfilled the following criteria:

1. The horse was in training (considering the age of the horse; for mature horses at least five training sessions/week).
2. No reports from the horse's rider or trainer of impaired performance in the horse and free from lameness according to the rider/trainer.

If the horse was not in full work or had impaired performance or lameness according to the rider/trainer, it was excluded from the study. The final decision on subject inclusion or exclusion was made by an ECVSMR-certified sports medicine specialist (M.R.).

Horses were recruited from three groups:

1. Cavalry horses (CH) from the Swedish Armed Forces (age range 5–21 years). These horses were used for ridden work, including general-purpose schooling, hacking, and jumping, road work at walk and trot, parades, and ceremonial duties.
2. Privately owned Warmblood horses (PH; age range 2–6 years). Horses ≥3 years old were used for ridden work, including general-purpose schooling, hacking, and jumping. The 2-year-old horse ($n = 1$) performed lunging exercises.
3. Standardbred trotters (ST) from two different professional trotting stables (age range 2–9 years). Horses ≥3 years old were in training and competing, while 2-year-old horses were in training.

Signed written owner consent was obtained for all horses and the Ethics Committee for Animal Experiments, Uppsala, Sweden, approved the study (Dnr 5.8.18-05197/2019).

2.2 | Data recorded

2.2.1 | Horse data

Signalment and relevant historical data, including any history of trauma or prior treatments, were retrieved from the medical database for horses when available or via an interview with the owner or trainer. Each horse was subjected to a full clinical examination and objective gait analysis, performed within 24 h before the ultrasonographic examination (M.R., E.H., and L.W.). Parameters recorded in the clinical examination included findings on palpation of joints, tendons, and ligaments and evaluation of hoof conformation.

2.2.2 | Objective gait analysis

Objective gait analysis was performed by using an inertial sensor-based system (Lameness Locator, Equinosis) comprising four inertial measuring units (IMUs). The IMUs were secured with tape and positioned on the mid-line of the horse at the highest point of the poll (attached to a poll cap), the highest point of the withers, and between the tuber sacrale. One IMU sensor was secured on the dorsal aspect of the right forelimb pastern to determine the timing of the right/left front and hind limb stance phase during the stride cycle. Measurements were obtained during trot in hand in a straight line on a hard surface, with the aim of including 25 strides per measurement.

Sensor data were collected at 200 Hz and analyzed using proprietary software (Equinosis). Vertical accelerometer data from the IMUs on the head, withers, and pelvis were double-integrated into positional data.[21] In the vertical position signal from each stride, two minimum and maximum positions were detected for the head, withers, and pelvis. For each stride, differences between the two pelvis minimal and maximal, respectively, were calculated and averaged for each measurement (PDmin/PDmax).[21,22] A mean value and standard deviation (SD) for all strides during a measurement were calculated. Positive values of a certain magnitude were taken to indicate an asymmetry attributable to the right fore- or hindlimb, and negative values of an asymmetry attributable to the left fore- or hindlimb. PDmin indicates a decreased vertical impact, that is, a weight-bearing lameness, and PDmax indicates a push-off lameness[23] with alterations in the propulsive phase of the stride.

Based on the straight-line measurements, horses were categorized as hindlimb lame or sound. Lameness was defined as an absolute value ≥6 mm for PDmin and/or PDmax with SD less than the respective mean. This threshold was chosen based on the clinical experience of asymmetry magnitude in lame horses since a low degree of movement asymmetries is very common in presumed sound horses in training where the presence of pain and pathology are unknown.[24]

2.2.3 | Ultrasonographic examination

All riding horses and a majority of the Standardbred trotters were sedated with detomidine hydrochloride (0.005–0.01 mg/kg body weight IV; Domosedan vet, Orion Pharma Animal Health) and butorphanol tartrate (0.005–0.01 mg/kg body weight IV; Butormidor vet, Salfarm Scandinavia) before the ultrasonographic examination. Following routine preparation (clipping of hair, washing with soap, and application of ultrasound gel), the horses were subjected to ultrasonographic examination of both stifles using an ultrasound machine (Logiq e, General Electric) with a variable frequency (8–12 MHz) linear transducer.

A full examination of all structures in both stifles was performed on all horses. The entire length of the PLs and the height and width of the IFP were evaluated in both transverse and longitudinal planes, with the horse bearing weight. Static and cine-loop B-mode and color Doppler ultrasonographic images (gain 20, scale 3 to −3 cm/s) were retrieved by an ECVDI-large animal diagnostic imaging resident (E.L.) or ECVDI-certified veterinary radiologist (M.U. and C.N.) and evaluations were made based on consensus agreement. The sonographers were blinded to the clinical findings and data from the objective gait analysis for the horses.

The IPL and medial patellar ligament (MPL) were considered normal if they had an even, distinct outline and were homogeneously echogenic throughout their entire length except in the distal portion, where hypoechoic, thin, radiating, evenly distributed striations were considered normal. The LPL was considered normal if it was homogeneous or mildly mottled in echogenicity throughout its entire length. Hypoechoic striations or gaps in the fiber pattern were considered normal in the most distal portion of the LPL.[4]

Hypoechoic areas within the PLs were subjectively categorized as either linear or core, distinct or indistinct, and hypoechoic or anechoic. The location of the findings was recorded as being in the cranial, caudal, central, medial, or lateral part and the proximal, middle, or distal third of the ligament. Blood flow (which could be caused by either neovascularization or inflammation) detected with color Doppler was subjectively graded as mild, moderate, or severe.

2.3 | Data analysis

Descriptive statistics were performed by the authors in collaboration with a professor of statistics in Microsoft Excel 2010. The association between ultrasonographic findings in the patellar apparatus, age, and hindlimb lameness (objectively measured movement asymmetry) was investigated.

First, a cross table with lameness against each of the ultrasonographic variables (hypoechoic areas, hypoechoic striations, enthesophyte formation) was made, and then an exact version of the chi-square test was used to quantify the associations. For cases where both variables had two levels, Fischer's exact test was used. The Freq procedure in the SAS (2017) package was used in both these analyses. The interpretation was based on the exact version of the Pearson chi-square test. Next, multivariable analysis was performed, and the association between lameness and ultrasonographic findings was investigated by stepwise logistic regression using the Logistic procedure in the SAS (2017) package.

The level of significance was set to $P < .05$ in all analyses.

3 | RESULTS

3.1 | Animals

In total, 116 horses were included in the study. Five horses (three Warmbloods and two Standardbreds [STB]) were excluded as they were not in full work.

Group CH: Fifty-eight horses from the Swedish Armed Forces were included. Their median age was 11 years (range 5–21 years). Breeds represented were Swedish Warmblood horses (n = 57) and Czech Kladruber (n = 1).

Group PH: Thirty-four privately owned young Warmblood horses were included. Their median age was 5 years (range 2–6).

Group ST: Twenty-four horses were included. Breeds represented were STB trotting horses (n = 23) and Swedish Coldblooded trotter (n = 1). Their median age was 4 years (range 2–9 years).

3.2 | Clinical examination

On palpation of the stifle joint compartments, none of the horses had marked effusion or increased heat. Palpation of the patellar apparatus, including the PLs, tibial tuberosity, and patella, revealed scar tissue in the skin and subcutis in the area of the proximal attachment of the LPL in one limb of one STB trotter. This horse did not react to palpation. The patellar apparatus was normal on palpation in all other horses. There were no horses with abnormal hoof conformation.

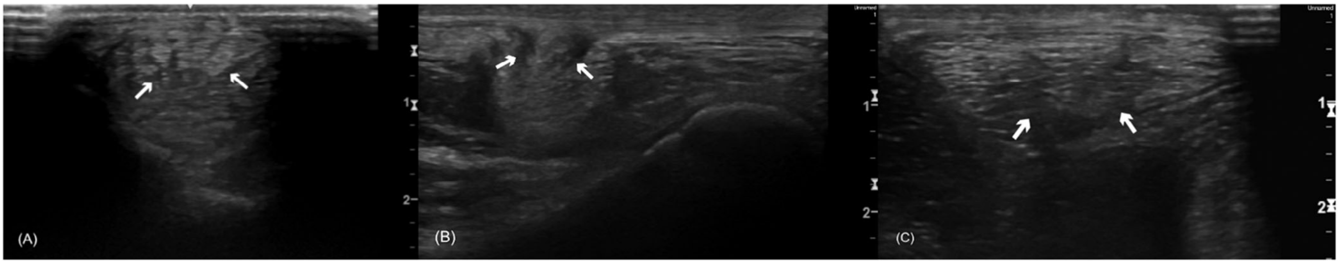

FIGURE 1 Transverse B-mode ultrasonographic images of patellar ligaments with normal appearance. (A) Thin, evenly distributed, hypoechoic radiating striations in the distal aspect of the intermediate patellar ligament, (B) hypoechoic invaginations in the cranial aspect of the medial patellar ligament, and (C) hypoechoic areas in the distal caudal aspect of the lateral patellar ligament (white arrows). Medial is to the left in the images, which were acquired with a linear transducer set at 12 MHz.

3.3 | Movement analysis

For each straight-line trot trial, 53 ± 20.8 (mean ± SD) strides were evaluated. Overall, 26 of the 116 horses studied (22%) had movement asymmetry above the lameness threshold in one or both hindlimbs (PDmin and PDmax on different limbs), according to our criteria. On group level, 13 CH (13/58, 22%), six PH (6/34, 18%), and seven ST (7/24, 29%) horses had signs of hindlimb lameness. Twenty-five horses had unilateral hindlimb lameness, while one horse had bilateral (PDmin and PDmax on different limbs) hindlimb lameness. Push-off (PDmax) lameness of the left hindlimb was detected in six horses and the right hindlimb in four horses. Impact lameness (PDmin) of the left hindlimb was present in three horses and the right hindlimb in nine horses. Two horses had both impact and push-off lameness of the right hindlimb, and one horse had both impact and push-off lameness of the left hindlimb.

3.4 | Ultrasonography

3.4.1 | Intermediate patellar ligament

Thin, radiating, evenly distributed, striations in the proximal and/or distal portion of the IPL were commonly seen (Figure 1). The striations in the proximal aspect of the IPL resembled striations described in the distal aspect of the ligament[3,5] and were considered most likely to be normal. The IPL had an oval to triangular shape in the proximal aspect, triangular to circular in its midportion, and triangular in the distal aspect (Figure 2).

Unevenly distributed, wide, hypoechoic, single, or multiple striations/splits were seen in either the distal portion (n = 14) (Figure 3) or proximal portion (n = 7) of the IPL in horses included in the study (bilaterally similar in six horses and unilateral in 15 horses).

In our study population, distinct or diffuse hypoechoic regions were commonly found in the IPL ($n = 24$; $n = 13$ bilateral similar, $n = 11$ unilateral) (Figures 4 and 5). This was a more common finding in the CH group (n = 17; 29%) than in the PH group (n = 4; 12%) or the ST group (n = 3; 13%). Hypoechoic areas were more commonly present in the middle third of the ligament (20/24; 83%) than in the distal (2/24; 8%) or proximal third (2/24; 8%) and were more commonly present in the caudal aspect (12/24; 50%) than in the central (10/24; 42%) or medial aspect (2/24; 8%). These areas were seen in both on- and off-incidence ultrasonographic images in transverse and longitudinal planes (Figure 6). All of these ligaments had a normal size, shape, and delineation. No color Doppler flow was detected within these hypoechoic areas or in surrounding normal hyperechoic ligamentous tissue.

Three horses (two from the CH group and one from the ST group) had enthesophyte formation at either the origin or insertion of the IPL. In one of these horses with bilateral hindlimb lameness, both IPLs showed enthesophyte formation.

3.4.2 | Medial patellar ligament

The MPL had a triangular shape throughout its entire length. In the most distal aspect, the ligament had a Y- or heart-shaped appearance, with hypoechoic periligamentous tissue entering the ligament from the cranial aspect (Figure 1). The most proximal aspect of the ligament had a diffuse hypoechoic appearance as fibers spread out into the parapatellar fibrocartilage.

In 17 horses, the MPL had a striated appearance in the most distal aspect (n = 13 unilateral, n = 4 bilateral similar appearance). Three cavalry horses (n = 1 unilateral, n = 2 bilateral similar) had diffuse or distinct hypoechoic areas in the distal third of the MPL. The hypoechoic areas were located in the medial aspect of the ligament in two of these horses and the caudal aspect in one horse. These regions could be seen on both on- and off-incidence ultrasound scanning (hypoechoic on on-incidence and hyperechoic on off-incidence scanning) and in both transverse and longitudinal planes. No color Doppler flow was detected within or surrounding the hypoechoic areas. Two of these horses were sound on objective gait analysis, and one horse with hypoechoic areas in both hindlimbs had unilateral hindlimb lameness.

One horse had a linear, diffuse hypoechoic area in the caudal aspect of the distal third of the ligament. In color Doppler, moderate flow was detected within the hypoechoic area in both transverse and longitudinal images (Figure 7). This horse also had mild enthesophyte formation

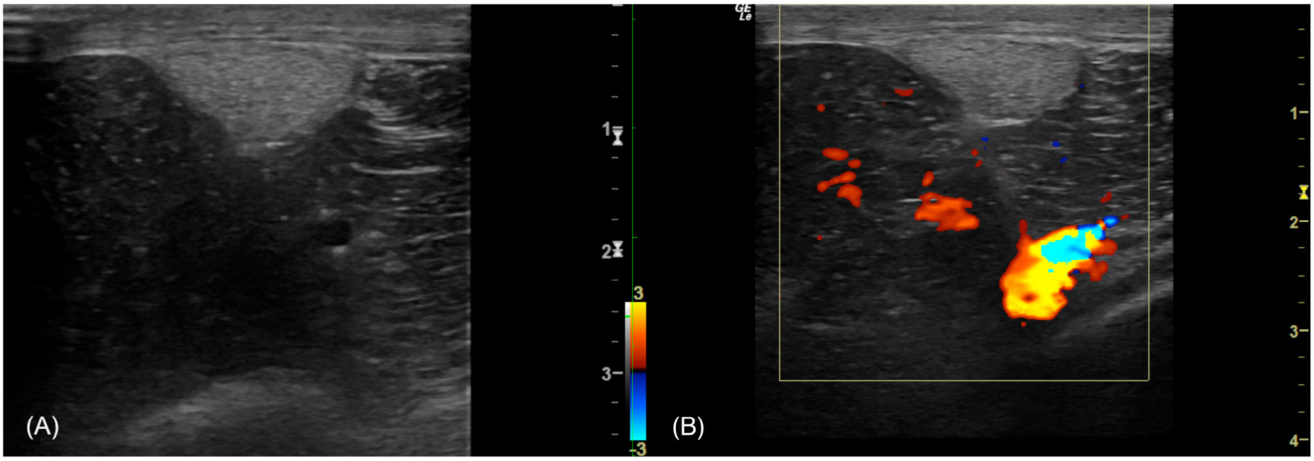

FIGURE 2 A, Transverse B-mode, and (B) color Doppler ultrasonographic images of the mid-third of the intermediate patellar ligament and infrapatellar fat pad in a 2-year-old Standardbred trotter. The ligament has a normal homogeneously echogenic appearance, and the fat pad is hypoechoic, with a large single vessel caudal to the ligament. Medial is to the left in the images, which were acquired with a linear transducer set at 12 MHz.

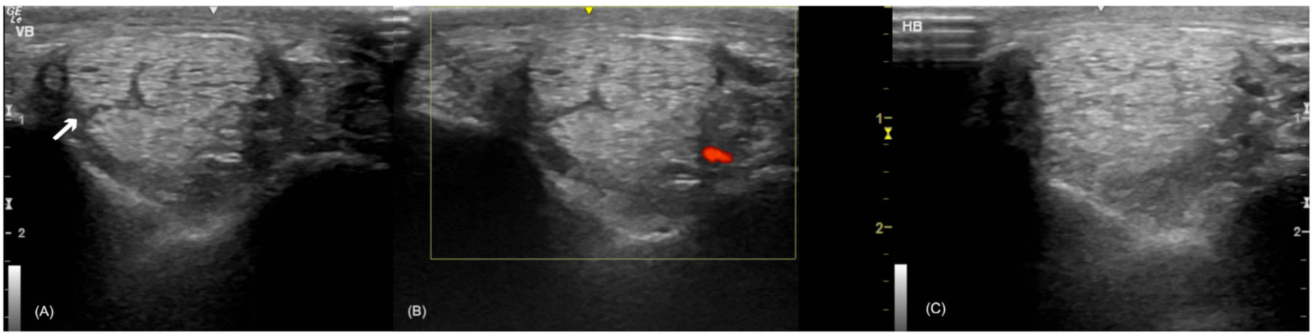

FIGURE 3 Transverse B-mode and color Doppler images of the distal third of the intermediate patellar ligament in a 6-year-old Warmblood horse with push-off lameness in this limb. A, Y-shaped striation present in the medial aspect of the ligament in the left hindlimb (arrow), (B) no color Doppler flow within or surrounding the striation. C, The intermediate patellar ligament in the right hindlimb had a normal appearance. Medial is to the left in the images, which were acquired with a linear transducer set at 12 MHz.

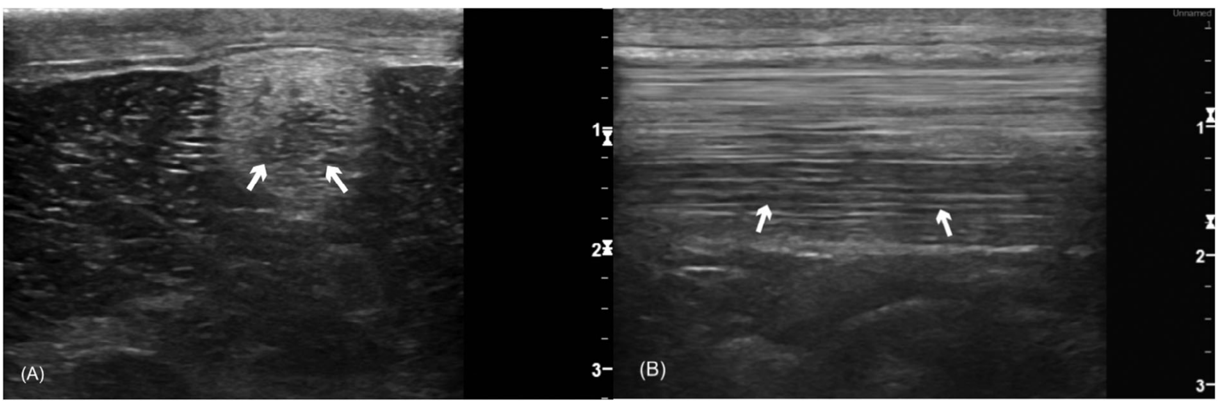

FIGURE 4 Transverse and longitudinal B-mode ultrasonographic images of the middle third of the intermediate patellar ligament in a 10-year-old Warmblood horse that was sound in this limb. An indistinct hypoechoic area is evident in the caudal aspect of the ligament in both (A) transverse and (B) longitudinal images (arrows). Medial and proximal are to the left in the images, which were acquired with a linear transducer set at 12 MHz.

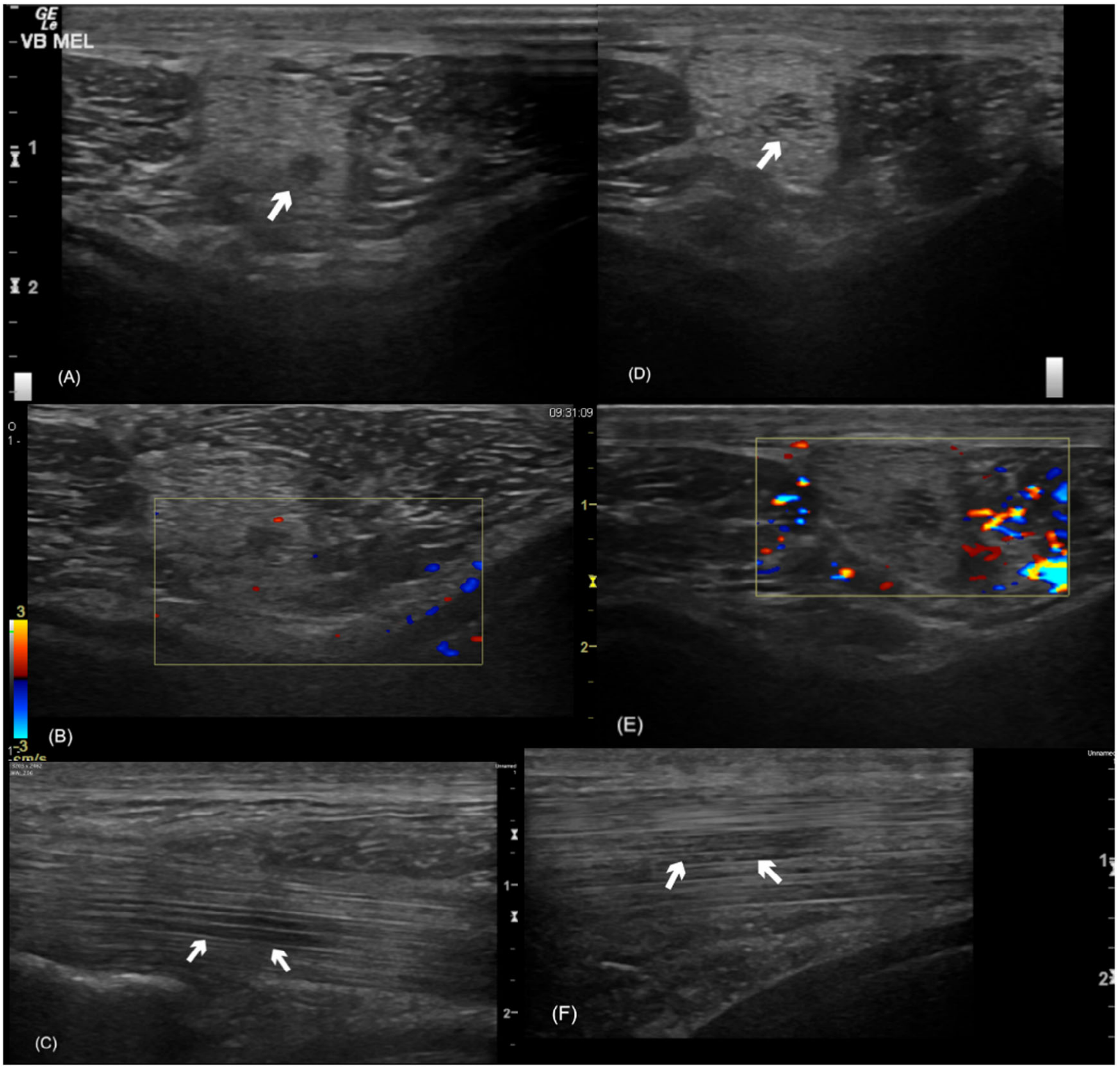

FIGURE 5 Transverse and longitudinal B-mode and color Doppler ultrasonographic images of the middle third of the intermediate patellar ligament in a 7-year-old Warmblood horse with an impact lameness in the left hindlimb. A–C, Distinct focal hypoechoic region present in the left hind intermediate patellar ligament, and (D–F) mildly more indistinct hypoechoic region in the right hind intermediate patellar ligament. No color Doppler flow was detected within the hypoechoic areas. Medial and proximal are to the left in the images, which were acquired with a linear transducer set at 12 MHz.

at the distal attachment of the MPLs bilaterally. The horse was sound according to objective gait analysis.

Eleven horses (all cavalry horses) had enthesophyte formation at either the origin or insertion of the MPL. Three of these horses were lame in the affected limb.

3.4.3 | Lateral patellar ligament

The LPL varied in shape and echogenicity along its length. It had an oval to triangular shape in the proximal aspect, with indistinct margins. In the middle third, the ligament was flattened and bilobed. In the distal aspect, the shape was oval to triangular, with variable echogenicity and fiber pattern. Distinct hypoechoic areas were commonly detected in the most distal aspect of the ligament at the insertion on the tibial tuberosity (47/116 horses, 39 horses bilaterally similar; Figure 1). These hypoechoic areas often disappeared on angling the transducer and were considered to represent obliquely oriented fibers.

In one horse, several linear, distinct hypoechoic areas/"splits" were identified in the central aspect of the distal two-thirds of the ligament (Figure 8). Mild color Doppler flow from vessels entering the hypoechoic areas from the caudal was observed. No color Doppler flow was detected in the normal hyperechoic ligamentous tissue. Multifocal, hyperechoic, shadowing areas were also present in the most distal aspect of the ligament with moderate enthesophyte formation on the tibial tuberosity. This horse had an impact and a push-off asymmetry in the affected limb.

Fifteen horses had enthesophyte formation at either the origin or insertion of the LPL (12/15 CH group). Four of these horses were lame in the affected limb.

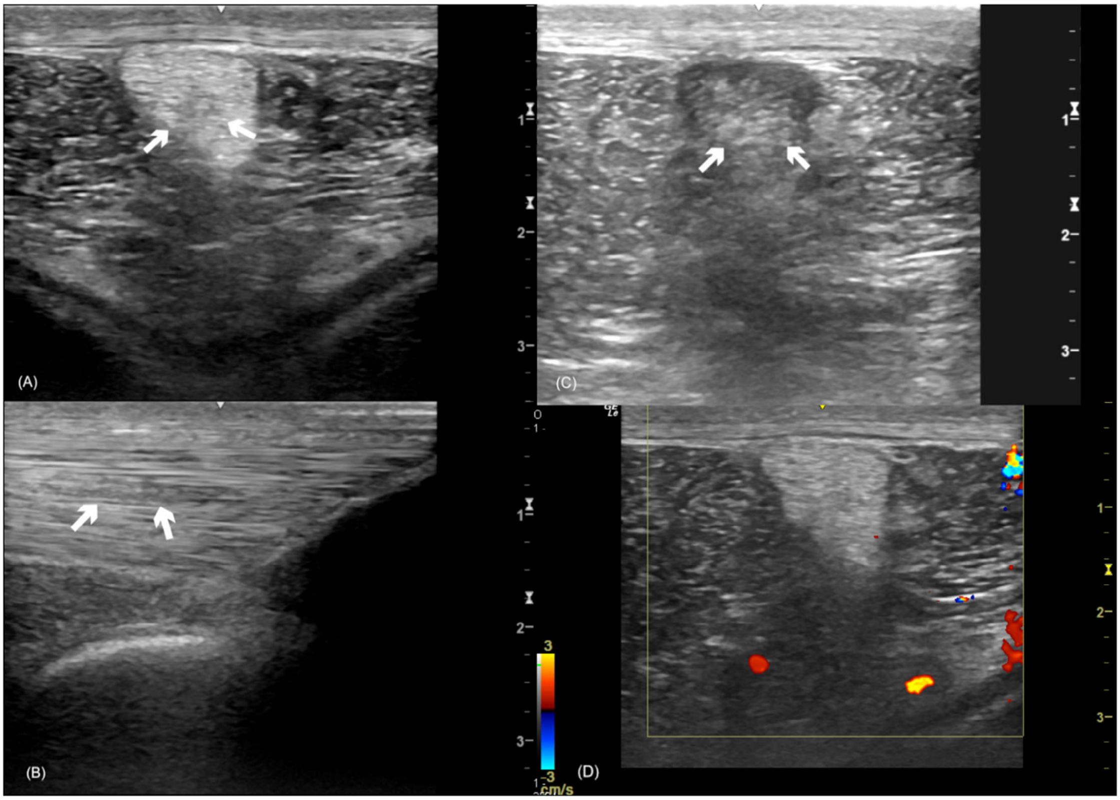

FIGURE 6 Transverse and longitudinal B-mode and color Doppler ultrasonographic images of the middle third of the intermediate patellar ligament in a 6-year-old Warmblood horse with a push-off lameness in this limb. A, B, Diffuse hypoechoic region present in the caudal aspect of the ligament on on-incidence ultrasound scanning and (C) diffuse hyperechoic region present on off-incidence ultrasound scanning (with the probe at a 45° angle to the tendon fibers). D, No color Doppler flow was detected in the on-incidence hypoechoic region. Medial and proximal are to the left in the images, which were acquired with a linear transducer set at 12 MHz.

3.4.4 | Infrapatellar fat pad

The IFP was hypoechoic in relation to the IPL, with hyperechoic linear striations (Figure 2). The most caudal part of the IFP, adjacent to the intercondylar groove, was often mildly more echogenic than the more cranial parts. The definition between the IPL and the IFP was distinct.

All horses had a similar pattern of vascularization of the IFP, as seen on color Doppler ultrasonography. One large vessel could be seen entering the fat pad from caudally at the mid-level of the IPL (Figure 2B) and splitting into two branches, one on either side of the IPL.

One horse with a diffuse hypoechoic finding in the mid-third of the IPL also had surrounding heterogeneous hyperechoic IFP. This horse had an impact lameness in this limb.

3.5 | Association between lameness and ultrasonographic findings

No association was found between the presence of lameness and ultrasonographic findings in the PLs or the IFP, as no variable reached the $P < .05$ level for significance in statistical analysis.

4 | DISCUSSION

Hypoechoic ultrasonographic findings in the PLs were common in the population of riding and trotting horses in training ($n = 116$) examined in this study. However, no association was found between ultrasonographic findings in the PLs and movement asymmetry/lameness detected in objective gait analysis. To our knowledge, only one previous study has described the ultrasonographic appearance of the stifles in active sports horses.[25] In that study, six of the 46 horses examined (13%) had hypoechoic or heterogeneous areas in the mid to distal aspect of the IPL, and one horse had a heterogeneous MPL.[25] Similar findings were made in the present study, where 19% of the horses had hypoechoic changes in the mid to distal portion of the IPL. As concluded in the previous study,[25] further research is needed to determine the cause and nature of these findings.

The PLs have previously been described as being fairly consistent in shape, with a similar uniform echogenicity and fiber pattern, and with smoothly defined ligament margins[2,3,5,14] except in the distal aspect of the IPL[3,5] and in the LPL.[4] Hypoechoic areas within the PLs have been reported to represent desmopathy,[2,3] but no previous study has compared hypoechoic ultrasonographic findings with histology.

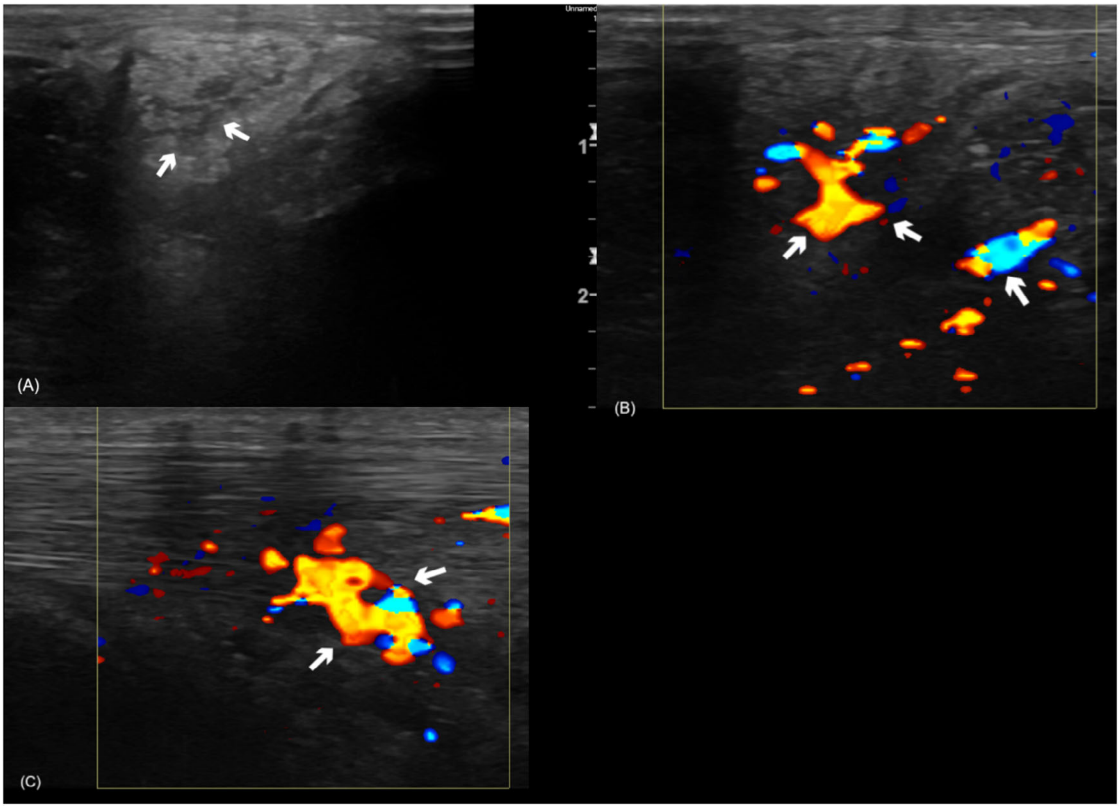

FIGURE 7 Transverse and longitudinal B-mode and color Doppler ultrasonographic images of the medial patellar ligament in a 15-year-old Warmblood horse that was sound according to objective gait analysis. A, Diffuse hypoechoic region in the distal third of the ligament, with (B, C) color Doppler flow both within and surrounding the ligament. A small enthesophyte was also present on the tibial tuberosity. Medial and proximal are to the left in the images, which were acquired with a linear transducer set at 12 MHz.

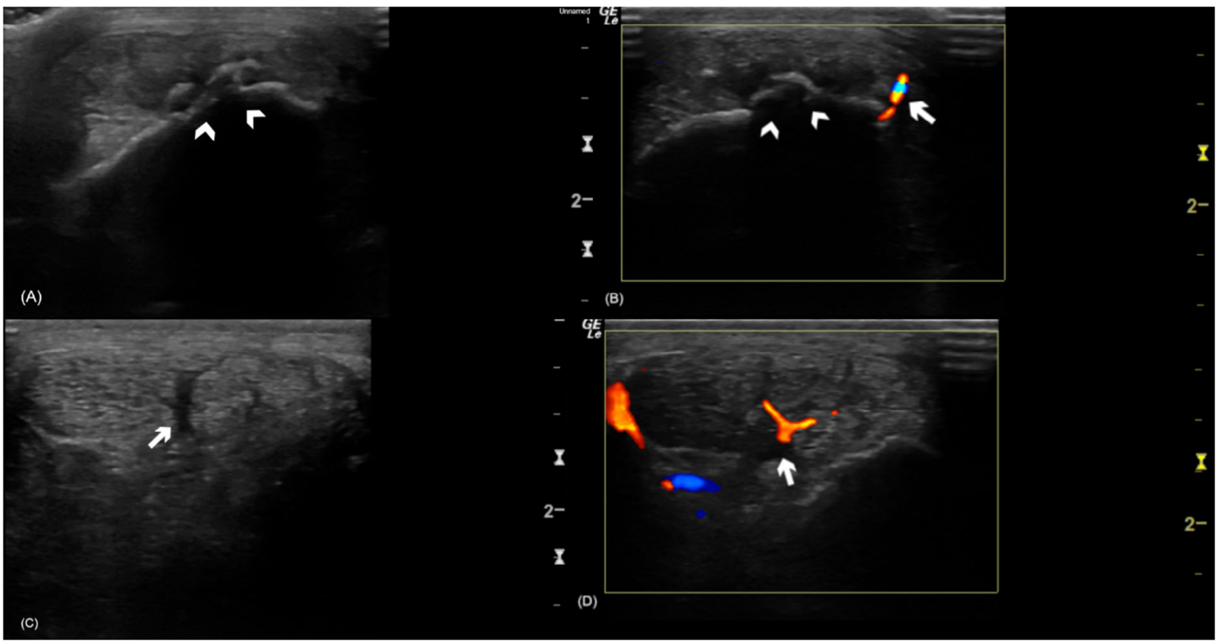

FIGURE 8 Transverse B-mode and color Doppler ultrasonographic images of the lateral patellar ligament (A, B) at the insertion on the tibial tuberosity and (C, D) at 2 cm proximal to the insertion in a 20-year-old Warmblood horse with impact and push-off lameness in the affected limb. A distinct linear hypoechoic region/“split” can be seen in the central part of the ligament (arrow in C), with color Doppler flow both within the hypoechoic region and surrounding the ligament (arrow in B, D). Moderate enthesophyte formation can be seen on the tibial tuberosity (arrowheads in A and B). Medial is to the left in the images, which were acquired with a linear transducer set at 12 MHz.

One study identified heterogeneous intermediate signal intensity in the PL in all MRI sequences in a group of asymptomatic horses.[26] Histologically, these areas represented fat infiltration between the collagen bundles, but this fatty tissue was distributed along the full length of all three PLs and was not concentrated in the middle third of the IPL, which was the most consistent location of hypoechoic areas in the present study.

A recent histological study investigating the PLs of eight healthy horses found high variability in the thickness of the endotenon and degree of fat infiltration.[27] The degree of fat infiltration significantly increased with age for the MPL and IPL.[27]

Chondroid metaplasia has been observed in both healthy and injured ligaments and tendons in the horse.[26,27,28,29,30] Focal chondroid metaplasia is a common finding in areas under compressive loadings, such as the sesamoidean segments of tendons.[29] An earlier study in humans found hypoechoic regions in the posterior aspect of the patellar tendon of asymptomatic athletes,[31] which was suggested to represent a pain-free adaptive response to compressive loading. It has also been suggested that the development of fibrocartilage in the human rotator cuff tendons may increase the resistance to compression but reduce the long-term resistance to tension, thus predisposing the tendons to rupture.[32,33]

The compressive and tensile forces acting on the PLs in horses have not yet been investigated; thus, it is not known whether compressive forces may lead to adaptive changes in the caudal aspect of the middle third of the IPL.

Patellar ligament desmopathy is generally considered to be uncommon in horses, but since the first case studies, ultrasonographic techniques have developed further, and image quality and resolution have improved. In recent studies, PL lesions have been identified more frequently in 4–18% of horses undergoing an ultrasonographic examination of the stifle.[3,4,5,25]

Previously injured PLs will often continue to display an abnormal ultrasonographic appearance despite the resolution of symptoms.[3] It is, therefore, likely that some of the ultrasonographic findings detected in the population of horses in the present study (especially in cases with concurrent changes in size, shape, and delineation of the ligament, vascularity, and enthesophyte formation) represent chronic desmopathies. However, since hypoechoic findings were present in a large number of the active horses studied, it is very unlikely that the ultrasonographic findings all represented chronic desmopathies. Oblique fiber orientation was also considered less likely, as the on-incidence hypoechoic areas became hyperechoic at all off-incidence angles.

In this study, horses were objectively assessed for the presence of gait asymmetries using an inertial sensor-based system. Definitive thresholds for pain-related clinical lameness have not yet been determined, and previous studies have demonstrated that different thresholds may be applicable depending on whether the system is used in the investigation of clinical lameness or for asymmetry screening.[24,34,35,36] Based on those studies, a threshold value of 6.0 mm for both PDmin and PDmax was used in the present analysis to classify a gait asymmetry as clinical lameness.

This is the first study to describe the appearance of the patellar apparatus using color Doppler ultrasonography. One large branching vessel was seen caudal to the IPL and was a consistent finding in all horses. This vessel is most likely a branch of the descending genicular artery, branching from the femoral artery at the level of the proximal thigh, supplying the IFP and the IPL in horses.[27,37]

Neovascularization is a common feature in humans with jumper's knee and Hoffa's disease.[10,38] One study found that human patients with ultrasonographic findings and neovascularization in and around the patellar tendon reported more pain than patients without neovascularization.[39] In the present study, no association was found between increased blood flow on color Doppler and lameness quantified with objective gait analysis. However, the study population consisted of active horses in training, and investigation of the association in a population of horses with PL desmopathy would possibly yield a different result.

This study has some limitations. The main limitation is that no regional or intra-articular local anesthetic blocking was performed to determine the clinical significance of any ultrasonographic findings detected or to locate the source of lameness. The objective measurements of the trot describe a general loading pattern of the limbs and not specifically of the stifle. What can be concluded, however, is that there is no strong association between ultrasonographic findings in the patellar apparatus and lameness. To get permission from owners and to economically finance blocking in such a large number of horses would be challenging; additionally, a method to block the PL has been developed but not yet validated.[40] As the analyses were performed on active riding and trotting horses, no histology could be performed. Furthermore, no follow-up was performed to investigate whether the ultrasonographic findings changed over time (which could provide more information regarding their cause and nature).

The results of this study can act as a starting point for further research on the possible role of the PLs in hindlimb lameness in horses and whether jumper's knee (chronic pain due to the patellar apparatus) exists in horses. A study comparing ultrasonographic findings with histological data is needed to distinguish pathology from normal anatomic variation and to avoid false-positive diagnoses in clinical practice. A larger study investigating the role of the IFP in horses with hindlimb lameness localized to the stifle and the correlation between neovascularization and lameness would be of great value.

In conclusion, hypoechoic ultrasonographic findings in the PLs were common in the population of active riding and trotting horses studied. Hypoechoic areas were commonly seen in the caudal aspect of the middle third of the IPL. No correlation was found between ultrasonographic findings and lameness in objective gait analysis. It is important to recognize there is biological variation in PL appearance, which may or may not be associated with pain in this area, therefore emphasizing the use of local analgesia to determine the location of the lameness.

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LIST OF AUTHOR CONTRIBUTIONS

Category 1

a. Conception and design: Rhodin, Uhlhorn, Hernlund
b. Acquisition of data: Law, Wright, Uhlhorn, Nilemo, Hernlund, Rhodin
c. Analysis and interpretation of data: Law, Wright, Uhlhorn, Nilemo, Hernlund, Rhodin

Category 2

a. Drafting the article: Law
b. Revising article for intellectual content: Law, Wright, Uhlhorn, Nilemo, Hernlund, Rhodin

Category 3

a. Final approval of the completed article: Law, Wright, Uhlhorn, Nilemo, Hernlund, Rhodin

Category 4

a. Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved: Law, Wright, Uhlhorn, Nilemo, Hernlund, Rhodin

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA ACCESSIBILITY STATEMENT

Data supporting the results are available from the corresponding author upon reasonable request.

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No previous presentation of the study.

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No reporting checklist was used.

ORCID

Ellen Law https://orcid.org/0009-0008-6889-7981

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