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The proximal aspect of the suspensory ligament in the horse: How precise are ultrasonographic measurements?

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Summary

Reasons for performing study: To evaluate intra- and interobserver variability in ultrasonographic measurements of the proximal aspect of the suspensory ligament (PSL) in the horse.
Hypothesis: A minimum difference of ≥20% is required to differentiate reliably between physiological and pathological alterations related to dimensions.
Materials and methods: Two operators examined the PSL in all 4 limbs of 14 horses twice using different techniques and different probes with and without standoff pads. Measurements were taken from the longitudinal and transverse images. Inter- and intraoperator variability was evaluated using agreement indices (AI) and the 95% limits of agreement (LOA).
Results: On the longitudinal scan the mean inter- and intraoperator AIs for dorsopalmar/-plantar thickness were both ≥0.89 and the 95% LOA were within target values for almost all intra- and interoperator comparisons. Similar mean AIs and 95% LOA were calculated for the dorsopalmar/-plantar thickness on the transverse image. For lateromedial width, cross-sectional area and circumference on the transverse scan, the mean inter- and intraoperator AIs ranged between 0.81 and 0.95 and the 95% LOA were higher than target values regardless of the imaging technique used. In general, better values for AIs and 95% LOA were achieved in the fore- compared with the hindlimb.
Conclusion and clinical relevance: Acceptable precision was identified within and between operators only for the dorsopalmar/-plantar thickness in longitudinal and in transverse scanning directions. For the lateromedial width, cross-sectional area and circumference, a relatively large variability was identified. This aspect has to be considered if these parameters are to be used for objective measurement of the PSL from the transverse ultrasound image.

Keywords: horse; suspensory ligament; ultrasonography; measurement; precision

Introduction

Lameness originating from the proximal suspensory ligament (SL) is common in horses [1,2]. Despite recent improvements in the diagnosis of proximal suspensory desmitis using a combination of advanced imaging modalities such as computed tomography (CT), scintigraphy and magnetic resonance imaging (MRI) [3], ultrasonography remains the imaging technique used most frequently to examine the proximal aspect of the suspensory ligament (PSL) and to monitor suspected lesions during recovery [4].

In ultrasonographic images, lesions of tendons and ligaments are evaluated by determination of the echo score (ES) and fibre alignment score (FAS) and by measuring the cross-sectional area (CSA) [5,6]. The ES and CSA are evaluated on the transverse image and the FAS on the longitudinal image. The ES is based on evaluation of the echogenicity and structure of a tendon or ligament. Acute tendon lesions appear hypoechoic, whereas in chronic lesions both hyper- and hypoechoic areas have been observed [5].

A wide variety in patterns of echogenicity may be observed in the normal PSL, mainly caused by the morphology of the proximal SL. It is bilobed in the forelimb and, to a lesser extent, in the hindlimb [7] and is composed of muscle and adipose tissue surrounded by collagenous (tendinous) tissue [7,8]. The amount of muscle and fat tissue in a horse is usually bilaterally symmetrical but varies between individual horses and breeds [8]. Different tissues have a large variation in echogenicity; central hypoechoic regions may even exist [5].

Another reason for the variation in echogenicity are the deep palmar/plantar vascular anastomoses that lie between the accessory ligament of the deep digital flexor tendon (ALDDFT) and the SL, or overlying tendons and ligaments, which create artifacts [6,9,10]. As a result of this variation in echogenicity, it can be very challenging to differentiate muscle fibres from lesions.

Although the FAS can be assessed in the PSL, this is considered to be a subjective method of evaluation, while measurements are viewed as a more objective way to detect pathological enlargement of the structure [11]. The aim of this study was to evaluate the inter- and intraoperator variability in ultrasonographic measurements of the origin of the SL in fore- and hindlimbs using different techniques and different transducers.

We hypothesised that a minimum difference of ≥20% is required to differentiate reliably between physiological and pathological alterations that are related to dimensions.

Materials and methods

Horses

The horses studied (8 mares and 6 geldings) were aged 5–28 years (median 15 years) and included 6 Standardbreds, 6 Arabian mix breeds, one Warmblood and one Quarter Horse. Average height at the withers was 156 cm (148–164 cm) and bodyweight ranged from 360 to 545 kg (mean 466 kg). The horses had to be sound to be included in the study and this was confirmed by the 2 operators prior to ultrasonographic examination.

Preparation of the limbs

All 4 limbs were clipped on the palmar/plantar aspect from the distal carpus/tarsus to the mid cannon bone. On the hindlimb, the clipped area was extended medially to allow good access to the PSL. The clipped area was scrubbed for 1 min using soap (Braunosan Vet)[a], subsequently cleaned with alcohol (Hospisept)[b] and covered with ultrasound gel (Sonosid)[c].

Ultrasonographic techniques and equipment

The images were obtained using a MYlab5 scanner[d] that included 2 different probes: a 7.5–12 MHz linear transducer and a 5–8 MHz microconvex transducer. In this study 12 MHz were used for the linear transducer and 8 MHz for the microconvex transducer. A field depth of 5 cm was selected. Gains for the linear transducer and the microconvex transducer were set at 76 and 58%, respectively. One focal zone was placed at the depth of the PSL. Longitudinal scans of fore- and hindlimbs were acquired in a weightbearing position using the linear transducer without a standoff pad (Fig 1).

Transverse images of the forelimb were obtained in 2 different limb positions: fully weightbearing and with the limbs lifted and the hoof fully

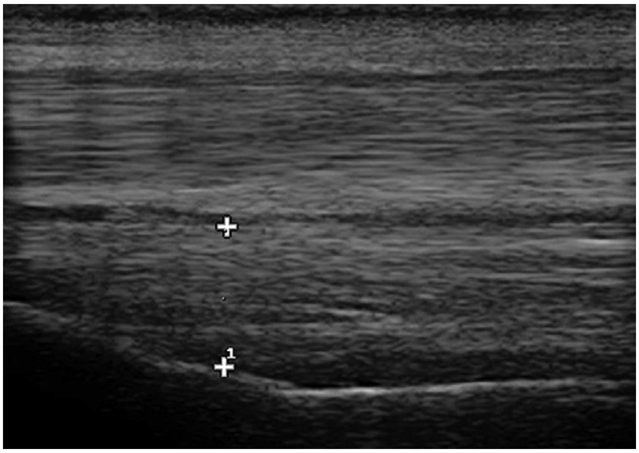

Fig 1: Hindlimb: longitudinal ultrasound image acquired with a linear probe. The dorsoplantar thickness (1) is measured at the most distal end of the attachment of the fibres to the proximal third metatarsal bone (MtIII).

flexed. In the weightbearing position the images were obtained using a linear transducer, with (Fig 2) and without a standoff pad, and using a microconvex transducer (Fig 3). In the flexed limb, the scan was performed using a linear transducer without standoff pad and using a microconvex transducer (Fig 4).

Transverse images of the hindlimbs were obtained using 2 different probes in the weightbearing position: a linear transducer, with (Fig 5) and without standoff pad, and a microconvex transducer.

Scans and measurements

On the longitudinal images, the dorsopalmar/-plantar thickness (DP) was measured at the most distal end of the attachment of the fibres to the proximal third metacarpal bone/third metatarsal bone (Mc/MtIII) (Fig 1). In the forelimb this image was taken from palmar in the sagittal plane. In the hindlimb the image was taken slightly plantaromedially just below the chestnut, where the sulcus between the superficial digital flexor tendon (SDFT) and lateral deep digital flexor tendon (DDFT) is palpable. For the transverse scan, 4 measurements were taken (Figs 2–5). The lateromedial width was measured at its greatest possible distance; the DP thickness was measured in the middle of the lateromedial width and perpendicular to it. The outlining border was used to measure the CSA as well as the circumference. In the image of the forelimb the SDFT had to be medial to the DDFT, the ALDDFT had to be rectangular in shape and the sagittal tuberosity of the McIII for attachment of the suspensory ligament had to be

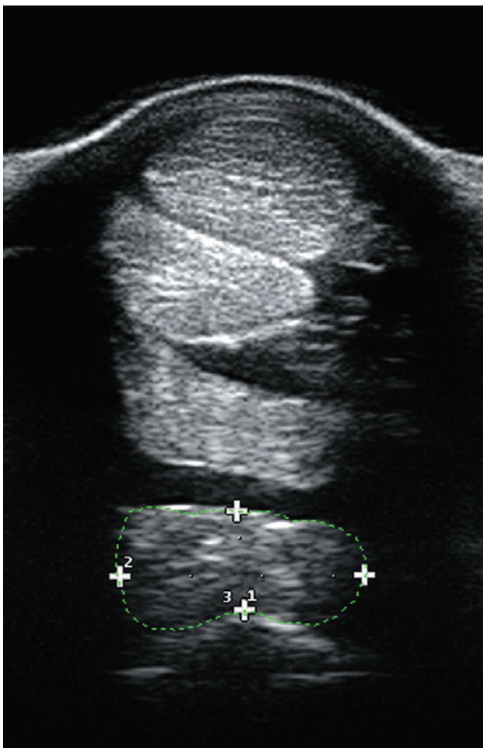

Fig 2: Forelimb: transverse ultrasound image acquired with a linear probe and a standoff pad with measurements of the dorsopalmar thickness (1), lateromedial width (2), cross-sectional area and circumference (3).

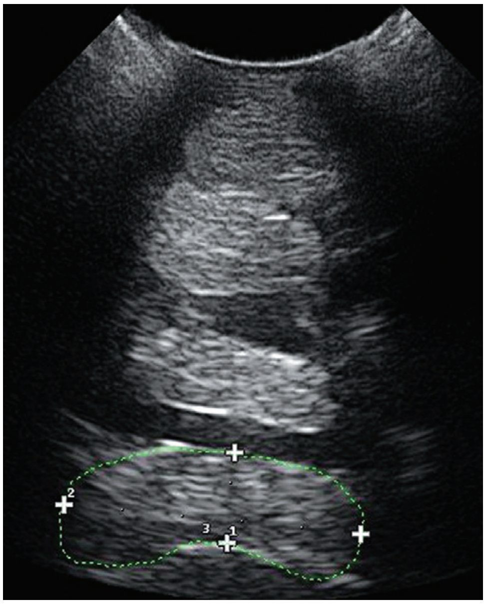

Fig 3: Forelimb: transverse ultrasound image acquired in weightbearing limb position with a microconvex probe with measurements of the dorsopalmar thickness (1), lateromedial width (2), cross-sectional area and circumference (3).

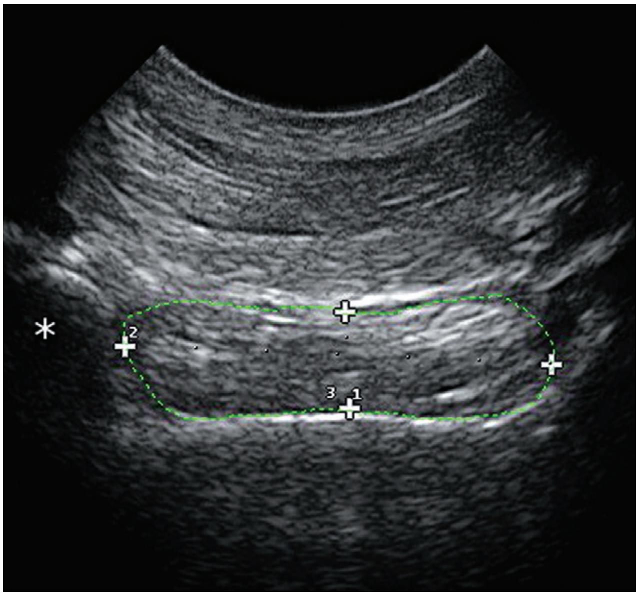

Fig 4: Forelimb: transverse ultrasound image in flexed limb position acquired with a microconvex probe with measurements of the dorsopalmar thickness (1), lateromedial width (2), cross-sectional area and circumference (3).* McIV.

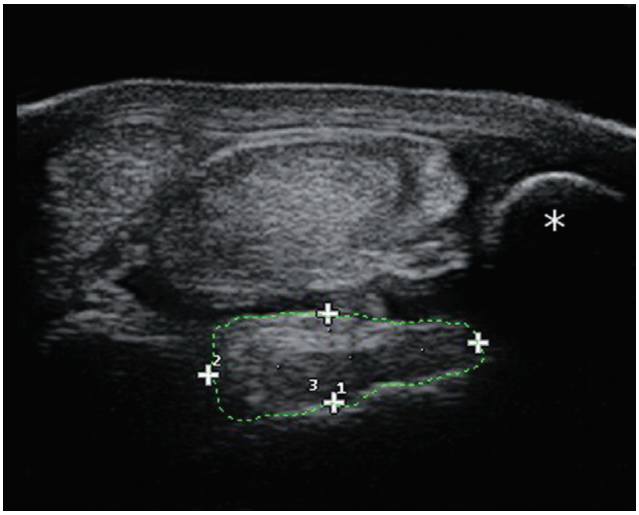

Fig 5: Hindlimb: transverse ultrasound scan with a linear probe with measurements of the dorsopalmar thickness (1), lateromedial width (2), cross-sectional area and circumference (3). * MT II.

visible. In the hindlimb the probe had to be held plantaromedially, distal to the chestnut [12]. In the image the rectangular SL lies below the DDFT and the SDFT is lateral to them. The lateral and medial borders of the SL lie between MtII and MtIV.

Two operators with experience in orthopaedic ultrasound imaged all legs of all the horses on 2 separate occasions. All images were saved in the scanner's archive. When the operators took measurements a tape was used to cover the results of the measurement in the left-hand corner of the scanner screen. The images with the measurements were again saved in the archive and the results recorded in a spreadsheet after all measurements had been taken. This ensured that operators were not aware of their results during the measurement process.

Data analysis

Repeatability

Inter- and intraoperator agreement indices (AI) were calculated for 28 fore- and 28 hindlimbs. Each operator obtained 588 measurements on the forelimbs and 364 on the hindlimbs. The following version of the AI equation was used [13–15]:

$$AI = 1 - [|X_a - X_b| / \{(X_a + X_b)/2\}].$$

For calculation of the interoperator AIs, X_a was the mean of the measurements acquired by the first operator, and X_b the mean of the measurements acquired by the second operator. For the calculation of the intraoperator AIs, X_a was the first measurement and X_b was the second measurement acquired by the same operator. The mean ± s.d (standard deviation) over all relevant measured limbs was calculated for the inter- and intraoperator AIs. An AI of one is considered to represent perfect agreement and AIs≥0.90 indicate excellent agreement [14,15]. An AI of 0.90 indicates that the absolute difference between 2 measurements amounts to 10% with respect to the mean of the 2 measurements.

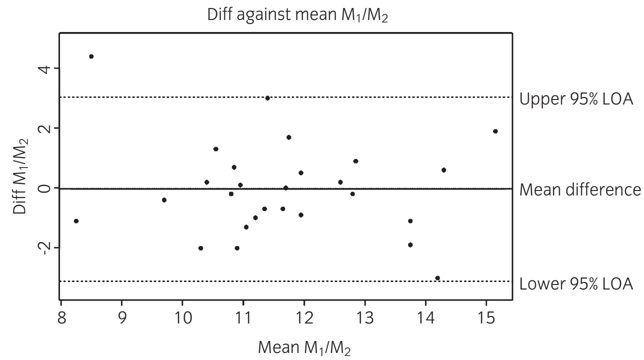

Fig 6: Bland-Altman scatter plot: Operator 1 intraoperator data for measurements of the DP thickness in the longitudinal ultrasound image in the hindlimb. Data points plotted are the differences between repeated measurements against the mean of the repeated measurements. The solid line represents the mean difference between the 2 operators' measurements and the broken lines represent the upper and lower 95% limits of agreement (LOA).

In addition, 95% limits of agreement (LOA) were calculated with LOA = mean difference ± 1.96 s.d. [16,17]. To check the suitability of the 95% LOA method, and consequently the assumption of approximate normality of the data, Bland-Altman plots of differences vs. mean of repeated measurers were constructed (Fig 6). The distribution of differences was evaluated with these scatter plots [15–17]. In addition, the null hypothesis of an underlying normal distribution was tested by appling a Shapiro-Wilk test (alpha = 0.05). The LOA gives an estimate of the potential range of differences for a wider population between the measurements made by observer 1 and observer 2 or between the first and the second measurement, respectively.

Given that no data are available that quantify a clinically significant enlargement of the origin of the suspensory ligament, the 95% LOA were compared with target values that represented approximately 20% of the measured values reported in earlier studies of the PSL: 3 mm (10–15 mm) for DP thickness and lateromedial width, respectively; 30 mm^2 for area (150 mm^2) [7] and 8 mm (40 mm) for circumference [18–20].

Results

Longitudinal images

Mean inter- and intraoperator AIs for the DP width were between 0.89 and 0.92 with s.d. between 0.11 and 0.06 for the fore- and hindlimb. Except for one measurement of the hindlimb, the 95% LOA were less than the target values for all intra- and interoperator comparisons (Table 1).

Transverse images

The mean inter- and intraoperator AIs for the DP thickness ranged in fore- and hindlimbs between 0.81 and 0.93 with s.d. of 0.14–0.06. The 95% LOA were less than the target values for all intra- and interoperator comparisons (Tables 2, 3).

TABLE 1: Intra- and interoperator agreement indices and 95% limits of agreement for measurements of the longitudinal scan of the fore- and hindlimb

			Forelimb		Hindlimb	
	TV		AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA
DP	3 mm	O 1	0.89 ± 0.09	-2.28–2.65	0.92 ± 0.09	-2.80–2.08*
		O 2	0.93 ± 0.06	-1.51–1.48	0.90 ± 0.11	-3.11–3.03
		IE	0.92 ± 0.05	-1.45–1.72	0.92 ± 0.07	-2.37–2.58

AI = agreement index; 95% LOA = limits of agreement; DP = dorsopalmar/-plantar, res. thickness; TV = target value; O 1 = operator 1; O 2 = operator 2; IE = interoperator; *not normally distributed.

TABLE 2: Intra- and interoperator agreement indices and 95% limits of agreements for measurements of the transverse scan of the forelimb

			Linear transducer with standoff pad		Linear transducer without standoff pad		Microconvex transducer		Linear transducer flexed carpus		Microconvex transducer flexed carpus	
	TV		AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA
DP	3 mm	O 1	0.91 ± 0.10	-2.20–1.53*	0.93 ± 0.08	-1.39–1.46*	0.86 ± 0.14	-2.09–2.42*	0.87 ± 0.08	-2.06–1.88	0.89 ± 0.08	-1.90–1.70
		O 2	0.88 ± 0.10	-1.78–2.45	0.86 ± 0.12	-2.38–3.34*	0.81 ± 0.13	-3.35–2.90	0.88 ± 0.10	-1.58–1.89	0.80 ± 0.14	-2.70–3.02
		IE	0.92 ± 0.07	-1.35–1.49	0.92 ± 0.08	-1.62–1.84*	0.86 ± 0.10	-2.53–0.84	0.89 ± 0.07	-1.52–1.71	0.87 ± 0.13	-1.39–2.52
LM	3 mm	O 1	0.87 ± 0.09	-6.17–5.74	0.85 ± 0.10	-5.90–6.57	0.90 ± 0.08	-7.06–7.03	0.90 ± 0.17	-10.71–8.44*	0.94 ± 0.06	-5.08–4.45
		O 2	0.85 ± 0.10	-6.45–5.33	0.87 ± 0.11	-5.89–6.58	0.89 ± 0.08	-7.17–7.10	0.92 ± 0.06	-5.46–6.00	0.90 ± 0.08	-7.74–8.19
		IE	0.89 ± 0.10	-4.86–5.78	0.90 ± 0.07	-4.83–3.30	0.89 ± 0.09	-6.88–7.64	0.92 ± 0.07	-5.93–5.26	0.93 ± 0.06	-4.84–5.81
CSA	30 mm^2	O 1	0.83 ± 0.14	-63.28–53.56	0.82 ± 0.13	-52.54–59.47	0.83 ± 0.14	-27.46–37.17	0.88 ± 0.07	-59.95–59.74	0.91 ± 0.30	-54.78–47.57
		O 2	0.86 ± 0.10	-42.20–44.13	0.84 ± 0.16	-50.54–66.41	0.86 ± 0.16	-84.20–74.78	0.89 ± 0.10	-68.75–60.82	0.88 ± 0.10	-62.25–72.68
		IE	0.86 ± 0.10	-46.23–44.06	0.87 ± 0.08	-45.02–24.77	0.84 ± 0.14	-80.98–65.23	0.91 ± 0.07	-43.35–50.92	0.87 ± 0.13	-53.90–90.72
C	8 mm	O 1	0.90 ± 0.08	-14.70–12.76*	0.88 ± 0.07	-12.38–13.54	0.90 ± 0.08	-18.03–17.19	0.92 ± 0.04	-12.69–10.75	0.95 ± 0.04	-8.61–8.70
		O 2	0.89 ± 0.07	-12.28–11.32	0.90 ± 0.08	-12.07–13.78	0.91 ± 0.09	-16.29–15.58	0.93 ± 0.06	-12.96–13.31	0.92 ± 0.07	-14.97–14.99
		IE	0.95 ± 0.05	-11.78–11.08	0.92 ± 0.05	-9.98–5.50	0.90 ± 0.08	-16.62–15.69	0.94 ± 0.04	-10.36–10.27	0.95 ± 0.05	-9.41–11.44

AI = agreement index; 95% LOA = limits of agreement; TV = target value; DP = dorsopalmar thickness; LM = lateromedial width; CSA = cross-sectional area; C = circumference; O 1 = operator 1; O 2 = operator 2; IE = interoperator; *not normally distributed.

For the lateromedial width the mean inter- and intraoperator AIs were between 0.84 and 0.94 with s.d. of 0.17–0.06, but all 95% LOA were greater than the target values for all intra- and interoperator comparisons.

For the CSA, the mean inter- and intraoperator AIs for fore- and hindlimbs ranged from 0.81–0.91 with s.d. of 0.30–0.10. All 95% LOA were greater than the target values that had been set for all intra- and interoperator comparisons (Tables 2, 3).

The mean inter- and intraoperator AIs for the circumference ranged between 0.84 and 0.95 in fore- and hindlimbs, with s.d. of 0.11–0.04. The 95% LOA were greater than the target values for all intra- and interoperator comparisons (Tables 2, 3).

There were no differences in the results for the linear transducer with and without standoff pad and for the microconvex transducer. There was no difference in the results when the forelimb standing position was compared with the flexed limb position.

Discussion

Excellent levels of intra- and interoperator agreement were identified only for the measurement of the DP thickness on the longitudinal scan. With one exception, the AIs were >0.9 and the upper and lower 95% LOAs were close to the predetermined target values for the DP thickness. Acceptable levels of intra- and interoperator agreement were identified for the DP thickness on the transverse scan. The AIs ranged between 0.81 and 0.93 and the 95% LOA were, with one exception, within target values. For all the other measurements, the AIs ranged between 0.81 and 0.95, but the 95% LOAs were greater than the target values. These results suggest that the most reliable ultrasonographic measurement of the dimensions of the proximal SL is the DP thickness obtained from the longitudinal scan, followed by the DP thickness obtained from the transversal scan. The other ultrasonographic measurements of the proximal SL are associated with considerable variation either within or between operators.

The high variability of measurements of the lateromedial width, circumference and CSA obtained for the PSL may be due to several reasons. First, the SL lies below the SDFT, DDFT and ALDDFT. Thus it is more challenging to evaluate and measure the PSL in the hindlimb because the structure is more completely enclosed by the splint bones than in the forelimb. This was reflected in the results of this study: the variability was less in fore- than in hindlimbs. Furthermore, tendons, ligaments and anastomotic veins between the ALDDFT and SL cause refractive scattering (edge shadowing). These hypoechogenic artifacts make it difficult to evaluate and measure the borders of the SL precisely [21]. Moreover, the difference in width between the SDFT, DDFT and the PSL makes it impossible to see the abaxial aspect of the PSL and therefore influences measurements. In addition, a limb will never be in exactly the same position as it was during an earlier examination and when the load on tendons and ligaments changes this alters the ultrasonographic appearance and consequently the results of the measurements. These uncertainties add up for inter- as well as for

TABLE 3: Intra- and interoperator agreement indices and 95% limits of agreement for measurements of the transverse scan of the hindlimb

			Linear transducer with standoff pad		Linear transducer without standoff pad		Microconvex transducer	
	TV		AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA	AI mean ± s.d.	95% LOA
DP	3 mm	O 1	0.93 ± 0.07	-0.97–1.10	0.87 ± 0.09	-1.51–1.51	0.85 ± 0.14	-2.09–2.33
		O 2	0.84 ± 0.11	-2.62–2.47	0.85 ± 0.10	-1.98–2.32	0.82 ± 0.10	-2.64–1.89
		IE	0.83 ± 0.12	-2.68–1.61	0.85 ± 0.14	-2.70–2.23	0.87 ± 0.11	-2.23–1.35
LM	3 mm	O 1	0.92 ± 0.06	-2.42–4.13	0.92 ± 0.07	-3.31–3.67	0.91 ± 0.06	-3.61–4.24
		O 2	0.89 ± 0.09	-5.46–5.11	0.85 ± 0.10	-5.99–7.06	0.86 ± 0.10	-6.33–6.77
		IE	0.91 ± 0.08	-4.85–1.85	0.87 ± 0.09	-6.32–2.27	0.84 ± 0.11	-8.82–4.40*
CSA	30 mm^2	O 1	0.87 ± 0.10	-17.40–32.77	0.88 ± 0.10	-24.00–28.86	0.87 ± 0.10	-27.46–37.17
		O 2	0.86 ± 0.12	-42.20–44.13	0.82 ± 0.13	-51.90–48.89	0.88 ± 0.10	-38.84–41.90*
		IE	0.82 ± 0.13	-50.00–21.90	0.81 ± 0.15	-55.40–27.26	0.82 ± 0.17	-65.83–36.80*
C	8 mm	O 1	0.94 ± 0.06	-5.65–9.34*	0.94 ± 0.05	-6.26–7.05	0.93 ± 0.05	-6.67–7.93
		O 2	0.90 ± 0.06	-11.65–10.70	0.88 ± 0.11	-12.07–13.78	0.91 ± 0.06	-10.39–10.81
		IE	0.86 ± 0.09	-14.81–2.21	0.86 ± 0.09	-15.38–2.40*	0.84 ± 0.11	-20.51–6.76

AI = agreement index; 95% LOA = limits of agreement; TV = target value; DP = dorsoplantar thickness; LM = lateromedial width; CSA = cross-sectional area; C = circumference; O 1 = operator 1; O 2 = operator 2; IE = interoperator; *not normally distributed.

intraoperator measurements and cause large variability in repeated measurements.

The lower variability for the DP thickness on the longitudinal scan can be explained by the fact that it is possible to determine precisely where to take the measurement in the sagittal plane because the most distal fibre attachment of the SL to the Mc/MtIII can be identified clearly on the ultrasonographic image. Furthermore, edge shadowing created by anastomotic veins is one of the causes of variations in echogenicity but on a longitudinal scan the borders of the SL are usually not affected by it. Hence, measurements are more precise on the longitudinal scan than on the transverse scan where edge shadowing caused by limited skin contact does affect the evaluation of the borders of the SL and therefore the measurements are less precise.

Intraoperator variability was similar for both operators in the forelimb, while in the hindlimb one operator's measurements had a higher variability than those of the other. This indicates that, when measurements are obtained for the hindlimb, which is probably more challenging than the forelimb, individual differences in variability exist even when the level of experience is comparable between operators.

In the forelimb the PSL is rectangular in shape and it is located plantar to the McIII, between McIII and McIII. In the transverse scan the bilobed structure is clearly visible. In the centre of each lobe, muscle tissue appears hypoechogenic on the ultrasonographic image [9] and may be misinterpreted as a pathological lesion. Since only sound horses participated in the study, the aim was to test the reliability for the DP thickness in a well defined localisation. In clinical cases measurements of the thickness of the PSL should be taken in the parasagittal and sagittal planes because lesions are located mainly in the medial and lateral lobes, respectively [9].

In the hindlimb the SL is rounder and it lies more laterally, rather than in the midline [7]. The PSL in the hindlimb is more enclosed by the splint bones than it is in the forelimb. When a plantaromedial approach is used, the SL lies dorsal only to the lateral DDFT and the ALDDFT. The echogenicity of the hindlimb SL is more consistent than that of the forelimb SL [22]. Lesions are more likely to occur in the centre of the structure [23] and generally appear as diffusely hypoechoic areas [24].

For evaluation of the reliability of the measurements obtained in this study, we limited the examination to the sagittal plane because we felt that this allowed a more consistent localisation of the ultrasonographic plane, both in the fore- and hindlimbs. However, in clinical cases, it is recommended that the thickness in the parasagittal plane is also measured because frequently lesions can be found in one of the lobes and therefore can be missed if the DP thickness is only measured in the sagittal plane.

The different methods used to acquire ultrasonographic images showed only small differences in their AIs, which were not statistically significant. In the lifted forelimb, the results for the lateromedial width, CSA and circumference had slightly higher AIs than in the weightbearing position (Table 2). This can be explained by the fact that, with the limb lifted, the whole PSL, both splint bones and the McIII can be seen in the ultrasonographic image. These bone lines are fixed points for measuring and therefore the measurements have lower variability. Furthermore, given that the SDFT and DDFT are pushed to one side by the probe, no refractive scattering interferes with the measurements in the way that it does in the full weightbearing position. However, in an image obtained with a lifted limb, lesions are probably harder to evaluate than in an image of a fully weightbearing limb. Therefore, the examination of the lifted limb can only be used as a complementary procedure [9]. In general, images acquired with a microconvex transducer are less affected by edge shadowing. Therefore including a microconvex transducer into the examination of the PSL can be helpful.

The data from this study raise the question whether comparison of measurements to reference values, even when measurements are taken in the longitudinal view, is appropriate in assessing whether the PSL is in a physiological or a pathological state. In particular, the CSA measurement, considered to be an extremely valuable tool in the diagnosis of changes in the PSL [25–27] and used in a prior study to diagnose proximal suspensory ligament desmitis [28], had low AI and LOA that were not within an acceptable range. This emphasises the importance of the SL qualitative assessment. However, at the origin of the SL, qualitative assessment can be very challenging as a result of variations in image quality and anatomy. In a thorough assessment of the structures, the echogenicity, fibre alignment, demarcation of the dorsal border and spaces between the PSL and Mc/MtIII and ALDDFT will have to be evaluated [24]. A comparison with the contralateral limb can be helpful.

In this study, no gold standard was used to determine the accuracy of the measurements because an earlier study had already shown that there is a substantial difference between an ultrasonographic image of the PSL and the MR image or a *post mortem* histological section [7]. Therefore, the decision was made that, in this study, the repeatability of ultrasonographic measurements was the focus of interest and not their accuracy.

For the 95% LOA an approximately normal distribution is required. Measurements not normally distributed should be evaluated with caution since they are not as reliable as results where the null hypothesis could not be rejected.

In conclusion, the findings of this study indicate that measurements of the dimensions of the proximal SL should be used with caution. The LOA reflects acceptable precision for the assessment of DP thickness on longitudinal and transverse scans, as long as the difference between the normal and enlarged PSL is greater than 20%. Owing to the difficulties associated with the ultrasonographic examination of the area, other measurements such as the LM width, circumference and area are less reliable and not recommended for clinical uses when determining the size of the proximal SL.

Conflicts of interest

No conflicts of interest have been declared.

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Manufacturers' addresses

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References

1. Dyson, S. (1991) Proximal suspensory desmitis: clinical, ultrasonographic and radiographic features. *Equine Vet. J.* **23**, 25-31.
2. Dyson, S. (2003) Proximal metacarpal and metatarsal pain: a diagnostic challenge. *Equine Vet. Educ.* **15**, 134-138.
3. Labens, R., Schramme, M.C., Robertson, I.D., Thrall, D.E. and Redding, W.R. (2010) Clinical, magnetic resonance and sonographic imaging findings in horses with proximal plantar metatarsal pain. *Vet. Radiol. Ultrasound* **51**, 11-18.
4. Rheimer, J.M. (2010) How to maximise image quality for the sonographic evaluation of the hind proximal suspensory ligament. *Proc. Am. Ass. equine practnrs.* **56**, 239-243.
5. Smith, R.K.W. (2008) Tendon and ligament injury. *Proc. Am. Ass. Equine Practnrs.* **54**, 475-501.
6. Edinger, J. (2010) Extremitäten. In: *Atlas der Ultraschalluntersuchung beim Pferd*, 1st edn., Ed: P.S. Glatzel, Schlütersche, Hannover. pp 18-77.
7. Bischofberger, A.S., Konar, M., Ohlerth, S., Geyer, H., Lang, J., Uletschi, G. and Lischer, C.J. (2006) Magnetic resonance imaging, ultrasonography and histology of the suspensory ligament origin: a comparative study of normal anatomy of Warmblood horses. *Equine Vet. J.* **38**, 508-516.
8. Gibson, K.T. and Steel, C.M. (2002) Conditions of the suspensory ligament causing lameness in horse. *Equine Vet. Educ.* **14**, 39-50.
9. Denoix, J.-M., Coudry, V. and Jacquet, S. (2008) Ultrsonographic procedure for a complete examination of the proximal third interosseus muscle (proximal suspensory ligament) in the equine forelimbs. *Equine Vet. Educ.* **3**, 148-153.

10. Rantanen, N.W., Jorgensen, J.S. and Genovese, R.L. (2010) Ultrasonographic evaluation of the equine limb: technique. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M. Ross and S. Dyson, Elsevier, St. Louis, Missouri. pp 182-205.
11. Pickersgill, C.H., Marr, C.M. and Reid, S.W. (2001) Repeatability of diagnostic ultrasonography in the assessment of the equine superficial digital flexor tendon. *Equine Vet. J.* **33**, 33-37.
12. Denoix, J.-M. and Farres, D. (1995) Ultrasonographic imaging of the proximal third interosseous muscle in the pelvic limb using a plantaromedial approach. *J. Equine Vet. Sci.* **15**, 346-350.
13. Filippi, M., Horsfield, M.A., Bressi, S., Martinelli, V., Baratti, C., Reganati, P., Campi, A., Miller, D.H. and Comi, G. (1995) Intra- and inter-observer agreement of brain MRI lesion volume measurements in multiple sclerosis. A comparison of techniques. *Brain* **118**, 1593-1600.
14. van der Vlugt-Meijer, R.H., Meij, B.P. and Voorhout, G. (2006) Intraobserver and interobserver agreement, reproducibility, and accuracy of computed tomographic measurements of pituitary gland dimensions in healthy dogs. *Am. J. Vet. Res.* **67**, 1750-1755.
15. White, J.M., Mellor, D.J., Duz, M., Lischer, C.J. and Voute, L.C. (2008) Diagnostic accuracy of digital photography and image analysis for measurement of foot conformation in the horse. *Equine Vet. J.* **40**, 623-628.
16. Bland, J.M. and Altman, D.G. (1986) Statistical methods for assessing agreement between two methods of clinical measurements. *Lancet* **i**, 307-310.
17. Bland, J.M. and Altman, D.G. (2003) Applying the right statistics: analyses of measurements studies. *Ultrasound Obstet. Gynecol.* **22**, 85-93.
18. Çelimli, N., Seyrek-Intas, D. and Kaya, M. (2004) Morphometric measurements of flexor tendons and ligaments in Arabian horses by ultrasonographic examination and comparison with other breeds. *Equine Vet. Educ.* **16**, 81-85.
19. Boehart, S., Arndt, G., Gmachl, M., Rindermann, G. and Carstanjen, B. (2010) Assessment of ultrasonographic morphometric measurements of digital flexor tendons and ligaments of the palmar metacarpal region in Icelandic horses. *Am. J. Vet. Res.* **71**, 1425-1431.
20. Boehart, S., Arndt, G. and Carstanjen, B. (2010) Ultrasonographic morphometric measurements of digital flexor tendons and ligaments of the palmar metacarpal region in haflinger horses. *Anat. Histol. Embryol.* **39**, 366-375.
21. Kirchberger, R. (1995) Imaging artifarcts in diagnostic ultrasound – a review. *Vet. Radiol. Ultrasound* **36**, 297-306.
22. Dyson, S.J., Arthur, R.M., Palmer, S.E. and Richardson, D. (1995) Suspensory ligament desmitis. *Vet. Clin. N. Am.: Equine Pract.* **11**, 177-215.
23. Denoix, J.-M. (1992) Images echographiques des lésions du muscle interosseux III (ligament suspenseur du boulet). *Prat. Vét. Equine* **23**, 23-33.
24. Dyson, S. (2007) Diagnosis and management of common suspensory lesions in the forelimb and hindlimb of the sport horses. *Clin. Tech. Equine Pract.* **6**, 179-188.
25. Reef, V.B. (1998) Musculoskeletal ultrasonography. In: *Equine Diagnostic Ultrasound*, 1st edn., Ed: V.B. Reef, Saunders, Philadelphia. p 61.
26. Whitcomb, M.B. (2004) Ultrasonographic evaluation of the metacarpus, metatarsus, and pastern. *Clin. Tech. Equine Pract.* **3**, 238-255.
27. Dyson, S. and Genovese, R. (2010) The suspensory apparatus. In: *Diagnosis and Management of Lameness in the Horse*, 2nd edn., Eds: M. Ross and S. Dyson, Elsevier, St. Louis, Missouri. pp 738-760.
28. Tóth, F., Schumacher, J., Schramme, M., Holder, T., Adair, H.S. and Donnell, R.L. (2008) Compressive damage to the deep branch of the lateral plantar nerve associated with lameness caused by proximal suspensory desmitis. *Vet. Surg.* **37**, 328-335.