Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Final report

Is there an equine "jumper's knee"? -An investigation of patellar desmopathy as a cause of stifle lameness in sports horses

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Part 1: Detailed summary

Mjukdelarna runt knäskålen (patella) som orsak till hälta hos häst är ett vetenskapligt outforskat område men som kliniskt ofta behandlas med "alternativa" metoder utan fastställd diagnos. Inom humanmedicinen är patellartendinos en utbredd verifierad diagnos. Degenerativa förändringar med patologisk kärl- och nervinväxt i patellarsenan tros vara orsak till smärtan. Motsvarande patologi, innervering av de olika mjukdelsstrukturerna runt knäleden samt diagnostik är dock dåligt beskriven i veterinärmedicinsk litteratur.
Syftet med denna studie var att beskriva patellarligamentens normala variation gällande anatomi, histologi samt ultraljudsutseende hos friska hästar. Syftet var även att utveckla ett standardiserat undersökningsprotokoll samt utveckla en metod för induktion av reversibel kortvarig lindrig hälta för att kunna utvärdera en metod för lokalbedövning av patellarligamenten. Syftet var också att undersöka vävnaden från hästar med onormala ultraljudsfynd i patellarligamenten för att förstå vad som händer i ligamenten på en cellulär nivå (histologiskt).

I detta projekt har vi studerat åtta hästar utan hälta från knäledsområdet med normala patellarligament vid ultraljudsundersökning. Hästarna skulle avlivas av annan anledning än deltagande i studien. Vävnad från patellas tre ligament samt fettkudden undersöktes histologiskt. Ligamenten har en blodförsörjning från två håll och har en riklig vaskulär arkitektur. Det finns en vaskulär förbindelse mellan ligamenten och fettkudden. Ett distinkt

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longitudinellt kärl gick in i varje ligament distokranialt. Histologiskt var det stor variation i tjockleken, samt kärl- och fettinnehåll i endotenierna. Metaplastiska tenocyter / chondroid metaplasi kunde ses i alla ligament från de vuxna hästarna vilket kan tolkas som en normalvariation.

Vi undersökte knälederna på 116 rid- och travhästar med ultraljud samt utförde rörelseanalys för att titta på normalvariation i en grupp av hästar i träning. Resultatet visade att ultraljudsfynd var vanligt framförallt i det mellersta ligamentet (24/116 hästar, 20,7%). Fettkudden hade ett hypoechoiskt utseende hos alla hästar utom en. Inget samband mellan ultraljudsfynd och hälta från den objektiva rörelseanalysen kunde ses vilket indikerar att många fynd inte orsakar smärta. Därför är det viktigt att man lägger bedövningar för att verifiera vilka fynd som orsakar en hälta.

I en annan del av projektet utvecklade vi en metod för reversibel induktion av hälta med hjälp av hyperton koksalt. Elva hästar inducerades och durationen av induktionen varierade mellan hästarna. På fem hästar lade vi en bedövning av patellarligamentet efter induktionen och för fyra av hästarna såg vi en markant skillnad. En av hästarna svarade dock inte på bedövningen vilket visar att inerveringen är komplex och att man måste tolka negativa resultat av denna bedövning med försiktighet.

Vi har gjort en sammanställning av nio kliniska fall med misstänkt desmit i patellarligamenten. Resultaten från klinisk undersökning, rörelseanalys, ultraljudsundersökningar samt bedövningar har beskrivits i detalj.

I den sista delen av projektet har vi undersökt hästar med onormala ultraljudsfynd i patellarligamenten. Hästarna har avlivats av andra orsaker än deltagande i denna studie. Vävnaden från friska samt onormala delar av ligamenten har tagits ur och undersökts histologiskt. Sammanställningen av fynden är inte klart i samband med rapporteringen men förväntas bli klart innan årsskiftet.
Projektet har gått enligt planen och vi har en doktorand anställd som kommer publicera de sista artiklarna från detta projekt inom kort.

Vi har publicerat två vetenskapliga artiklar och ett abstract och en tredje artikel är inskickad för granskning. Vi har presenterat resultaten på tre vetenskapliga konferenser. Resultaten har även förmedlats vid föreläsningar nationellt samt internationellt för praktiserande hästveterinärer. Vikten av att verifiera bilddiagnostiska fynd med bedövningar har även förmedlats vid flertalet populärvetenskapliga presentationer för professionella samt lekmän inom hästnäringen. Planen är publicering av ytterligare tre vetenskapliga publikationer varav två redan är i manusform och resultaten från dessa kommer att spridas via utbildningar för kliniskt verksamma veterinärer och lekmän.

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Part 2: Main report

Introduction

Background and objective.

Historically, the patellar ligament region has attracted much attention from veterinary practitioners as a possible source of equine hind limb lameness with subsequent decreased performance. While the upward fixation of the patella is obvious and easy to diagnose - the limb being fixed in a persistent straight position - more subtle movement disturbances from this area are often vaguely described as knee "instability" or "weakness," without further specific diagnostic criteria.
To treat such perceived "instability", varying "alternative treatments" such as skin blistering, periligamentous blistering and ligament splitting have been, and still are, applied with varying results. Today, periligamentous blistering, using vitamin C, has gained substantial popularity among trainers, horse owners and veterinarians, even though we have yet to scientifically document and explain: the pathogenesis of the "disease" of instability; the mechanism of this particular treatment; and the outcome of blistering. Thus making this particular treatment regimen illegal.

Based on our equine clinical work, concurrent with a careful literature study of comparative cases in human orthopaedics medicine, we hypothesize that there is a new equine pathology, to be unravelled and defined in the extra-synovial structures of the stifle, that contributes to lameness, an analogue to human athletes' "jumper's knee". In the clinic, we have observed, with the use of high-tech objective motion analysis methods, a surprisingly high prevalence of "push-off lameness" where propulsion is decreased in one hind limb. This observation indicates that the pain causing lameness is not primary provoked by a loaded joint. Because such a load would, in theory, create an "impact-lameness". Having investigated a number of such horses thoroughly, our pilot data suggest that this push-off lameness is indeed caused by pain and pathology in the patellar ligament region.

Objective motion analysis systems help unravel the biomechanics of lameness but does not adequately address the diagnosing of soft tissue pathology, calling for a multi-modal investigative approach. Therefore, we propose a scientific anatomic, clinical and pathological study of this particular region and the subsequent lameness it may produce with the use of a stellar multi-modal team of veterinary diplomates in sports medicine, surgery, diagnostic imaging and pathology. Once a scientific foundation has been documented from such a broad perspective on soft tissue pathology, appropriate diagnostic sound methods may be developed.

We expect the results to contribute to evidence-based management of horses with pathology of the patellar regions as well as improved equine veterinary diagnostic tools for the clinical assessment of the patellar ligament area. The latter will include an objective description of specific movement aberrations, an ultrasound imaging atlas of the region, and procedures for diagnostic analgesia.

If the pathology of this region is similar to what is documented in human athletes, we expect to be able to transfer considerable knowledge from the modern treatment and rehabilitation regimens of human athletes. Thus, our tools will pave the way for development of evidence-based methods of treatment. Subsequently, these tools may be used to evaluate and explain the possible effects of the "alternative" blistering performed today.

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The primary aim is to explore the potential role of patellar desmopathy in chronic hind limb lameness in sports horses. Specific aims include the:

1) description of normal anatomy, histology and imaging
2) description of a systematic clinical examination methodology and diagnostic imaging procedure
3) description of the ultrasonographic appearance of the patellar ligaments (PLs) and infrapatellar fat pad in a population of horses in active training and to relate the ultrasonographic findings to objectively measured movement asymmetry.
4) investigate methods for diagnostic analgesia in this region
5) exploration of the pathological anatomical findings and pathophysiological mechanisms in the patellar ligaments by advanced imaging techniques and histological methods.

Material and methods

A literature review has been performed to investigate knowledge gaps within this subject (1).

1) **Description of normal anatomy, histology and imaging**- The current study describes the PL and infrapatellar fat pad (IFP) vascular pattern from computed tomography scans of barium perfused normal equine specimens (n = 8; age 10 days to 18 years), as well as routine histology to serve as a reference for future investigations into PL pathology and IFP disease (2).

2) **Description of a systematic clinical examination methodology and diagnostic imaging procedure.** Ultrasound imaging of 10 sound horses and 9 clinical cases with earlier diagnosed patellar desmopathy have been included. An examination protocol for the patellar ligaments and infra-patellar fat pad has been developed using B-mode ultrasound and doppler (to evaluate vascularization). An ultrasound atlas describing the imaging pathology of the patellar ligaments and the infra-patellar fat pad has been developed.

Nine clinical cases from the University equine hospital were included in a case study. The horses underwent a clinical examination including diagnostic analgesia, objective motion analysis, ultrasonographic examination (3).

3) **Investigation of the association between ultrasonographic changes of the patellar ligaments and objectively measured push-off lameness**.- One hundred sixteen riding and trotting horses were included in the study. B-mode and color Doppler ultrasonographic examination of both hind patellar apparatus and objective gait analysis were performed on all horses. The association between ultrasonographic findings, age and movement asymmetry during trot was investigated.

4) **Investigate methods for diagnostic analgesia in this region**

Lameness originating from pain in the intermediate patellar ligament corresponding to anterior knee pain was induced by injection of hypertonic saline, a locally irritating but short-acting substance used in pain research in human volunteers, in the ligament in one of the hind limbs. In horses that developed a consistent lameness a local anaesthetic was injected around the ligament to evaluate if it is possible to block the pain pathway from the ligaments and horses were followed over time to determine if the induced lameness would return as the effects of the local anaesthetic wear off.

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This report is the first to describe hypertonic saline injections as a reversible method to induce lameness of short duration in horses. A method to block pain and lameness originating in the intermediate patellar ligament is described. This can be used in clinical cases with suspicion of clinically significant lesions in the patellar ligaments.

5) **Exploration of the pathological anatomical findings and pathophysiological mechanisms in the patellar ligaments by advanced imaging techniques and histological methods.**

The aim of the current study was to by histological postmortem examination investigate, what the hypoechoic areas commonly detected in the patella ligaments of horses with B-mode ultrasound, represent.
In total eleven horses were included in the study. The median age of the horses was 12 (8-26 years). Three horses had distinct or indistinct hypoechoic regions in the IPL. One horse had a normal appearance of the three patellar ligaments on on-incidence ultrasound scanning but when angling the probe for off-incidence ultrasound diffuse hyperechoic tissue could be seen in the middle third of the IPL. Two horses had distinct hypoechoic regions in the MPL
One horse had an indistinct hypoechoic region in the LPL. Three horses had normal ultrasonographic appearance of both hind patellar ligaments.

One horse with abnormal ultrasonographic findings on the intermediate patellar ligaments was identified in the teaching herd. The findings were similar bilaterally and were not associated with clinical symptoms or lameness. An ultrasound-guided biopsy procedure was performed on the standing sedated horse under local anaesthesia. Histopathology results are pending and we anticipate that these will give insight into which tissue corresponds to the often identified hypoechoic regions in the ligaments.

Results and discussion

The literature review concludes that further studies are required to describe ultrasonographic normal variation of the patellar ligaments, pathological changes verified by histopathology, and their progression in healing. Further, the regional innervation and specific placement of diagnostic anaesthesia to verify pain originating from the ligaments should be investigated (1).

1). Results: The patellar ligaments (PLs) received a bipolar blood supply. Vascular architecture consisted of numerous distinct longitudinal vessels with several horizontal connections, which branched into extensive latticeworks of smaller vessels throughout the ligaments. Several vascular connections between the PLs and the infrapatellar fat pad (IFP) were identified. One distinct longitudinal vessel was seen entering each of the IFP lobes at the distocranial aspect, branching extensively into lobar vascular networks which anastomosed by several horizontal branches at the mid portion of the IFP where the two lobes merge. Histologically, there were large variations in PL interfascicular endotenon thickness, vascularity and fatty infiltration; these parameters increased with age for the intermediate and medial PL. Areas of metaplastic tenocytes / chondroid metaplasia were identified in all investigated adult medial PLs; in 2/7 in the intermediate PL and in 4/7 in the lateral PL. The adult IFP consisted of white unilocular adipose tissue, organized in lobules separated by thin connective tissue septa increasing in thickness towards the periphery and the distocentral aspect (2).

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2)The developed examination protocol for the patellar apparatus worked fine. Horses with patellar ligament pathology responded variably to i.a. stifle anesthesia. Patellar ligament infiltration anesthesia was positive in 5/7 horses non-responsive to intra-articular anesthesia, 2/9 horses were negative to both. Neovascularization of equine patellar ligaments has not been reported previously and the association with injury, healing and pain is not known. Hind-limb push-off lameness may be associated with patellar ligament desmopathy (3).

3) Ultrasonographic findings in the PLs were common in this population of active riding and trotting horses. 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 in one horse where it was hyperechoic. No association could be found between ultrasonographic findings in the patellar apparatus and movement asymmetry. One example of abnormal findings is given in figure 1

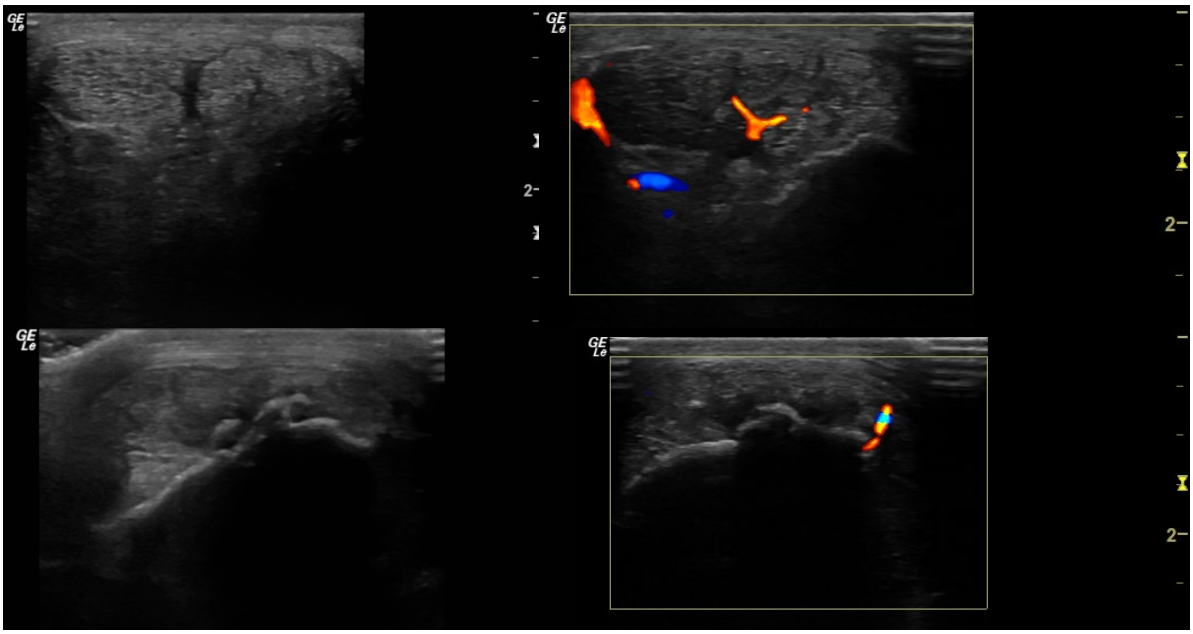

Figure 1 Example of hypoechoic finding in the LPL with intra-ligamentous color Doppler flow. Transverse B-mode (a,c) and color Doppler (b,d) ultrasound images 2cm proximal to the distal attachment of the LPL on the tibia tuberosita and at the distal attachment of the LPL (c,d) in a 20-year-old Warmblood horse (OWB group). The ligament is mildly enlarged and has several distinct hypoechoic regions with color Doppler flow within. Moderate enthesophyte formation of the tibial tuberosity. This horse had a mild impact and a mild push-off asymmetry on this limb. Medial and proximal is to the left in the image; the image was acquired with a variable frequency linear transducer set at 7.7MHz.

4) In total, 11 horses were injected with 4 ml of hypertonic saline in the intermediate patellar ligament of one hind limb. All horses had induced lameness in the injected limb. The duration of lameness was from 30 minutes to >300 minutes. Five horses were subsequently injected with local anaesthetic solution around the ligament. Lameness improved/was abolished in 4/5. In 1/4 lameness returned as the effects of the local anaesthetic wore off (figure 2).

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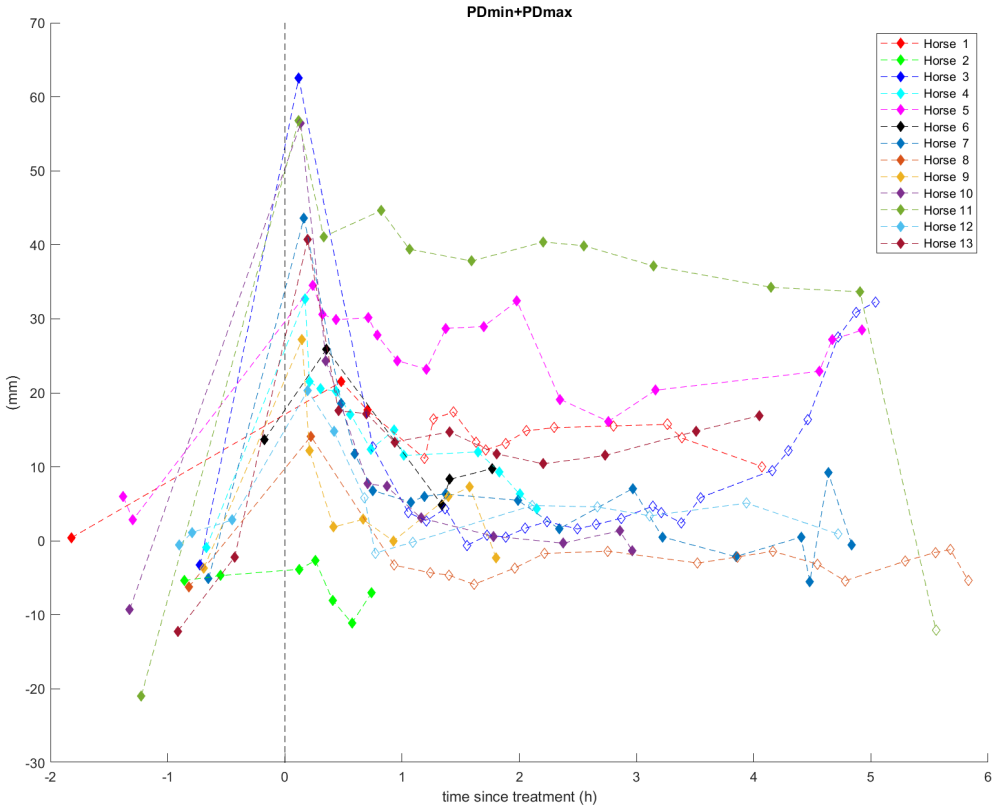

Figure 2
Data from motion analysis before and after induction of lameness from the intermediate patellar ligament is presented on the y-axis where zero is perfect symmetry and higher values indicate lameness. The x-axis indicate time (hours) where the induction is indicated at 0 dotted vertical line. Empty squares indicate measurements after diagnostic analgesia in 5 horses.

In one horse the intermediate patellar ligament was injected with a lower dose, 2.5 ml, of hypertonic salaine. This horse did not become lame following injection.
In one horse the lower dose, 2.5 ml, of hypertonic saline was injected periligamentous. This horse developed a lower-grade lameness of shorter duration.

5) We are still working on the histological results which will give us more information on when ultrasonographic findings are related to pathology. The results will be published at the end of 2023.

Conclusions

The equine PLs and IFP are highly vascularized structures with ample vascular connections suggestive of crosstalk. This, together with the large variation in PL endotenon thickness, vascularity and fatty infiltration, should be taken into consideration when assessing potential PL histopathology as these changes increase with age and are found in horses without clinical signs of stifle disease. Metaplastic tenocytes / chondroid metaplasia should be considered a normal finding throughout the medial PL and is not age dependent. The role of the equine IFP in stifle disease has yet to be elucidated (1).

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We have for the first time used a new model of reversible lameness in horses that can be used for studying lameness originating from anatomical structures as ligaments or tendons. This method can be used to evaluating different analgesic methods for localizing pain in horses. Our approach for local anesthesia of the patellar ligament was successful in 4 out of 5 horses indicating that that the innervation of this area is complex. A negative response to a block in this area can´t exclude pain from this area.

Ultrasonographic findings in the PLs were common in a population of active riding and trotting horses. No correlation could be found between ultrasonographic findings and lameness from objective gait analysis. The biological variation in the appearance of the PLs are important considerations during the routine ultrasonographic examination, to identify pain-related pathology in this area. This also highlights the importance of using local analgesia to decide when ultrasonographic findings are the cause of lameness during lameness examinations.

The method for diagnostic analgesia of the patellar ligament in this study can have false negative results and therefore needs to be interpreted with caution when lameness is not abolished.

Relevance for the practical horse sector incl. recommendations

Describe how the project results can be used in the practical horse sector, what is needed for the results to be implemented, and (if applicable) what needs further investigation after the project.

This study shows that the biological variation in the appearance of the PLs are important considerations during the routine ultrasonographic examination, to identify pain-related pathology in this area. It is not possible from the ultrasonographic examination to determine if the abnormal findings are painful or not. This also highlights the importance of using local analgesia to decide when ultrasonographic findings are the cause of lameness during lameness examinations.

The method for diagnostic analgesia of the patellar ligament in this study can have false negative results and therefore needs to be interpreted with caution when lameness is not abolished.

References

1) L. Wright, E. Hernlund, C. Fjordbakk, B. Ytrehus, E. Law, M. Uhlhorn and M. Rhodin. (2022) Patellar ligament desmopathy in the horse - a review and comparison to human patellar tendinopathy (‘Jumper’s knee’), Comparative Exercise Physiology. https://www.wageningenacademic.com/doi/pdf/10.3920/CEP220011

2) Fjordbakk CT, Marques-Smith P (2022). The equine patellar ligaments and the infrapatellar fat pad – a microanatomical study. BMC Veterinary Research,DOI 10.1186/s12917-023-03579-3

3) Patellar ligament desmopathy in sports horse hind limb push-off lameness. Rhodin, M., Wright, L., Hernlund, E., Persson-Sjödin, E., Ekman, S., Grabski, M., Uhlhorn, M. (2019) 28th ECVS Annual Scientific Meeting, Hungary, July 4-6 2019. https://core.ac.uk/download/pdf/222452345.pdf

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Part 3: Result dissemination

State all result dissemination from the financed project into the appropriate section, including information as indicated in each section. Additional rows can be added to the table.

Scientific publications, *published*	*Author(s), year, title, journal, Vol, No, pp., doi-link*
	L. Wright, E. Hernlund, C. Fjordbakk, B. Ytrehus, E. Law, M. Uhlhorn and M. Rhodin. (2022) Patellar ligament desmopathy in the horse - a review and comparison to human patellar tendinopathy ('Jumper's knee'), Comparative Exercise Physiology. https://www.wageningenacademic.com/doi/pdf/10.3920/CEP220011
	Fjordbakk CT, Marques-Smith P (2022). The equine patellar ligaments and the infrapatellar fat pad – a microanatomical study. BMC Veterinary Research,DOI 10.1186/s12917-023-03579-3
	Patellar ligament desmopathy in sports horse hind limb push-off lameness. *Rhodin, M., Wright, L., Hernlund, E., Persson-Sjödin, E., Ekman, S., Grabski, M., Uhlhorn, M. (2019)* 28th ECVS Annual Scientific Meeting, Hungary, July 4-6 2019. https://core.ac.uk/download/pdf/222452345.pdf
Scientific publications, *submitted*	E. Law, L. Wright, M. Uhlhorn, C. Nilemo, E. Hernlund, and M. Rhodin (2023).Hypoechoic ultrasonographic findings in the patellar ligaments are common in riding and trotting horses in training (116 cases). Veterinary Radiology & Ultrasound
Scientific publications, *manuscript*	E. Law, F. Södersten, L. Wright, M. Uhlhorn, E. Hernlund, and M. Rhodin Patella Ligaments in Horses: A Correlative Ultrasonographic and Postmortem Study in Asymptomatic Horses.
	L. Wright, E. Law, M. Uhlhorn, E. Hernlund, and M. Rhodin Lameness induction and diagnostic anesthesia in the equine patellar ligament
Conference publications/ presentations	Patellar ligament desmopathy in sports horse hind limb push-off lameness. *Rhodin, M., Wright, L., Hernlund, E., Persson-Sjödin, E., Ekman, S., Grabski, M., Uhlhorn, M. (2019)* 28th ECVS Annual Scientific Meeting, Hungary, July 4-6 2019. https://core.ac.uk/download/pdf/222452345.pdf
	Desmit i patellarligamenetet hos sporthästar med frånskjutshälta. *Rhodin, M., Wright, L., Hernlund, E., Persson-Sjödin, E., Ekman, S., Grabski, M., Uhlhorn, M.* Veterinärkongressen 2020
	Ultrasonographic Appearance of the Patella Ligaments in 58 Horses in Training. *Ellen Law, Margareta Uhlhorn, Linda Wright, Marie Rhodin* Veterinärkongressen 2021
	Title, year/date, group presented to (link if applicable)

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Oral communication, ***to horse sector, students etc.***	I have been invited for lectures and courses for veterinarians and lay people as a specialist on objective gait analysis and orthopedics. In equine orthopedic diagnostics, it is common that the veterinarians use ultrasound to diagnose lameness without confirming the association of the findings with pain/lameness. Therefore, I presented results from this project where we in the ultrasound study showed the difficulties in relating ultrasound findings to lameness without performing diagnostic analgesia. These results have been very important for me to convincing people that diagnostic analgesia often needs to be used. This knowledge is also important for riders and trainers to be aware of the limitations when diagnostic analgesia is not used and they can select veterinarians/clinics that do proper lameness examinations.
	2023-04.19 Värmlands Ridsportförbund, professional equestrian trainers. Lecture by Marie Rhodin
	2022-11-28 and 2023-02-01 ATG-talang ridsportförbundet, talent program for young riders. Lecture by Marie Rhodin
	2022-11-09 Älvsered, professionals within saddle fitting, Lecture by Marie Rhodin
	2022-04-11 Romme racetrack, Lay people and professional trainers within the trotting industry Lecture by Marie Rhodin
	2022-09-17International Society of Equine Locomotor Pathology. Lecture by Marie Rhodin.
	2022-08-28Sporthorse medical diagnostic centre (SMDC)-Education for equine orthopaedics (Marie Rhodin and Elin Hernlund).
	2023-02-11 Utrecht, Equine Gait Analysis Society- Lecture Marie Rhodin Equine practitioners from different countries.
	2023-02-16 Portugal, Course in Equine Gait Analysis, three days of lectures and practical demonstrations (Marie Rhodin). Equine practitioners from different countries.
	2022-03-02 Evidensia Helsingborg-Marie Rhodin education for equine orthopeadics at Evidensia horse clinic.
Other	News letter SLU https://www.slu.se/forskning/kunskapsbank/publicerat/sport--och-sallskapsdjur/hastnotiser/kan-hastar-drabbas-av-hopparkna/
	The knowledge from this study is implemented in the teaching at the Veterinary Program at SLU

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