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Research article

Superficial digital flexor tendinitis treatment using high-intensity laser therapy and therapeutic ultrasound in polo ponies

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Abstract

High-intensity laser therapy (HILT) is an alternative technique that should provide better results than therapeutic ultrasound in the treatment of tendinitis. However, there has not yet been a study to support this hypothesis in horses, especially in polo ponies. This study aims to follow up the outcomes of high-intensity laser therapy and therapeutic ultrasound in tendinitis polo ponies in Thailand. Twelve limbs with tendinitis from 10 ponies were included in the study after lameness examination; the limbs were confirmed to have tendinitis via ultrasonography. The ponies were randomized to high-intensity laser therapy and therapeutic ultrasound group. Recordings of the severity of the cross-sectional area (CSA), echogenicity score, fiber alignment score (FAS), lameness examination and pain responsive were performed on day 0, day 8, day 30 and day 60. The samples were randomized to six limbs in each treatment group. The results show that there was no significantly change in the CSA within treatment groups (HILT: P = 0.2; therapeutic ultrasound P > 0.9) and between the treatment group (P > 0.9), echogenicity score or FAS within and between the treatment group in 60 days of study. None of the ponies in this study experienced skin reactions from the treatment. In conclusion, both high-intensity laser therapy and therapeutic ultrasound are safe to use in the tendinitis of polo ponies and have the ability to decrease inflammation. However, a rehabilitation program is still the most important part that should be controlled along with the treatment.

Keywords: High-intensity laser therapy, Polo pony, Superficial digital flexor tendinitis, Therapeutic ultrasound, Ultrasonography

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INTRODUCTION

Tendinitis is a common and important musculoskeletal problem in horses due to the long recovery and high risk of re-injury rate; these can make tendinitis a career-ending problem and causing to economic loss (Goodrich, 2011; United States Department of Agriculture, Animal and Plant Health Inspection Service, 2001). Due to the ponies' intense workload, polo is considered to be a high-risk sport (Inness and Morgan, 2015a; Costa-Paz et al., 1999). That leads to high risk of musculoskeletal injury. One study in polo ponies showed that the most common injury found is tendon injuries (4.3%; 95% CI 2.9–5.7) (Inness and Morgan, 2015b) and the most frequently affected tendons are the superficial digital flexor tendon (SDFT) and suspensory ligament (SL) (Kasashima et al., 2004; Murray et al., 2006; Williams et al., 2001) due to their functions of storing energy and supporting the metacarpophalangeal joint movement. Therefore, diagnosis includes observation, palpation, lameness examination and confirmation by ultrasonography, which is considered to be the standard method of tendinitis diagnosis. Due to the prolong healing process of tendinitis, many treatment modalities have been applied to shorten the recovery period and promote the proliferative and remodeling phases that know is the important phase of fibroblast and collagen synthesis and new fibers alignment takes place to make the injured tendon return as normal as possible (Goodrich, 2011; Thomopoulos et al., 2015; Lipman et al., 2018). The treatments include systemic anti-inflammatory medicine, topical treatment, regenerative treatment, surgery and rehabilitation, but the treatment outcomes vary and no best treatment has been determined so far (Witte et al., 2016; Geburek et al., 2016; Geburek et al., 2015; Ho et al., 2014).

Among those treatments, High-Intensity Laser Therapy (HILT) is the latest non-invasive remedy. It is also applied in human physiotherapy to contribute to increasing blood flow (Larkin et al., 2012) and stopping inflammation by increasing nitric oxide (NO) production in the mitochondria. It acts to inhibit respiration by binding to cytochrome C oxidase (COX; NO-COX binding). Moreover, the light absorption by the chromophores results in the increasing of adenosine triphosphate, RNA, or DNA production (photochemistry effects) and results in tissue stimulation (photobiology effects) (Santamato et al., 2009). HILT was found to be efficacious treatment for the reduction of pain and loss of strength in chronic tendinopathy; neck, shoulder, and back pain; and knee osteoarthritis cases in humans (Roberts et al., 2013). These factors make HILT a popular treatment these days. While, the therapeutic ultrasound emits unfocused sound waves that may have the potential to penetrate underlying tissues. The mechanisms of actions through thermal and non-thermal effects are increase in blood circulation (Baker et al., 2001), prolonged nerve transmission velocity (Dunn and Frizzell, 1990), increase the cell membrane potential, permeability and transport mechanism. Some data showed that the ultrasonic waves can promote collagen synthesis and arrangement (Faric et al., 2013; Faric et al., 2018). The vibrations from the sound wave are also believed to create micro-currents of liquid and cavitation, which may cause tissue destruction (Dunn and Frizzell, 1990). In human physiotherapy, the therapeutic ultrasound is used as an alternative treatment and also a substitute for the laser therapy due to the lower price. Moreover, a study in human shown the same treatment outcomes with these two techniques (Demir et al., 2004). Therefore, these treatments should be interchangeable as well to treat tendinitis in horses. Therefore, the aim of this study is to follow up the treatment outcomes of HILT and therapeutic ultrasound in polo ponies in Thailand.

MATERIALS AND METHODS

All polo ponies used in this study were approved by a consent form authorized by ownership. The animal care and use protocol was approved by the faculty of veterinary medicine of Chiang Mai university's animal care and use center; FVM-ACUC Ref. No. R14/2561.

Animals

The Argentine polo ponies used in this study were between the ages of 8 and 18, were mixed gender, and had developed superficial digital flexor tendinitis during the 2019-2020 polo season. This study included both new and re-injuries (Figure 1). Only the SDFT was used to follow up on the ponies who had been diagnosed with combined tendinitis and desmitis. The ponies who assigned to treat with other treatment, the ponies that did not allow the touching of the legs without sedation and the ponies who were retried during the study were exclude from the study. The tendinitis polo ponies which fitted with the inclusion criteria in this study were simple randomized into each group of treatment.

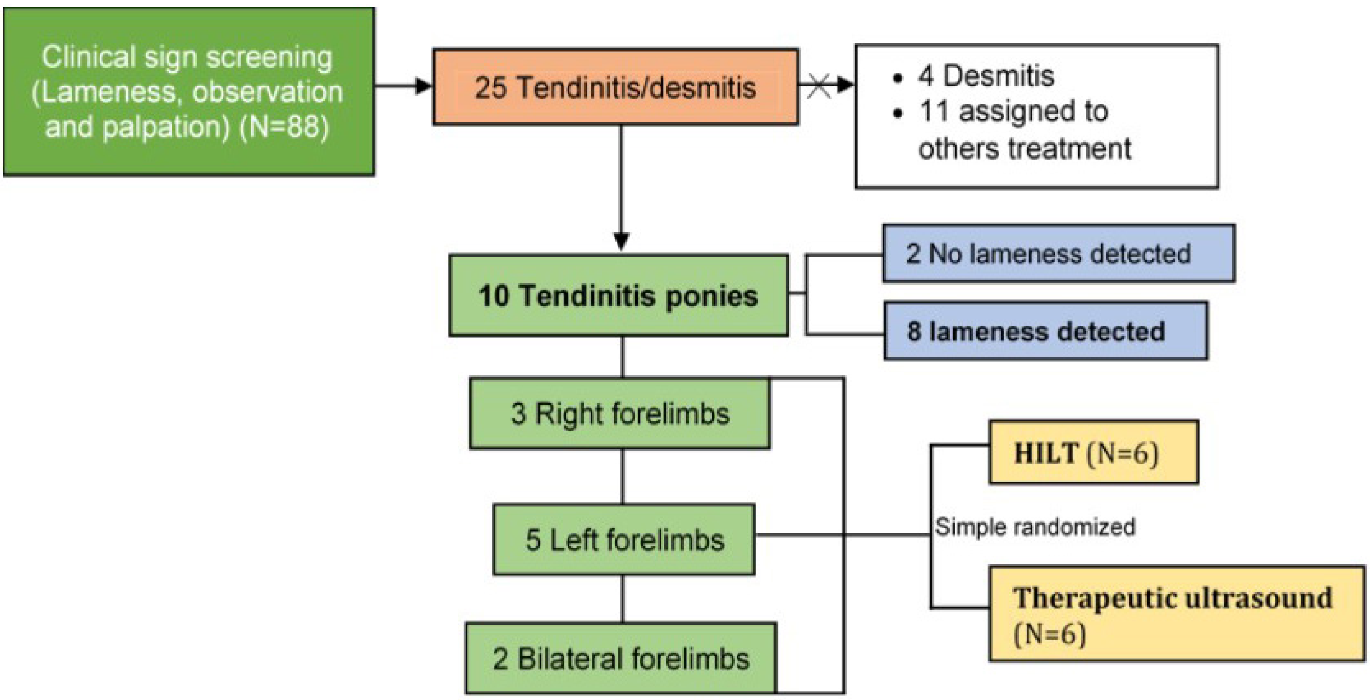

Figure 1 The sample selection and treatment allocation via simple randomization.

Lameness examination

A protocol of examination was adapted from the standard protocol (Baxter and Stashak, 2011) and routine lameness checkup of polo club. Lameness signs were detected during daily exercise on a packed sand training track or by an observation of asymmetrical tendon structure compared to the contra-lateral side. The ponies who showed at least one of these would be taken for an individual check on a hard-ground surface and were recorded by the video camera (Sony Handycam: HDR-PJ720E; Sony Europe B.V., Weybridge, United Kingdom). Lameness was assessed by subjective and objective measurements. The subjective examination was scored independently by 2 veterinarians on a scale from 0-5 (Ross, 2008).

The objective measurement was done by using an inertial sensors system (Lameness locator®: Equinosis,LLC, Columbia, United States). Three wireless sensors were placed on the body of the pony, the fist sensor was placed on top of the pony's head between both ears, the second sensor was placed on the dorsal aspect of right front leg pastern area, and the last sensor was placed on dorsal midline of the hip region. Video was recorded throughout the examination, and the results were blinded from the two veterinarians who observed the lameness. The ponies were trotted in a straight line on hard-ground surface for 50 meters going back and forth to the examiner, then lunging on hard ground in a 3- to 5-meter diameter for 3 lapses for each left and right lunge. Afterward, full limb flexion tests were performed on all four legs.

After lameness detection, hoof tester and hoof hammer were used to evaluate the hoof pain, then palpation and manipulation were performed to define the painful structure and the trigger point.

Ultrasound examination

The ultrasonographic examinations were performed by a veterinarian throughout the study after lameness examination by confining the ponies in the stock and immobilizing them with xylazine HCl (X-LAZINE 10%: L.B.S. LABORATORY LTD.,) 100 mg/ml (0.25-0.5 mg/kg) intravenously. The palmar, median and lateral areas of the distal limb cover of both suspensory branches were clipped by No. 50 clipper blade, then the hair-clipped area was cleaned thoroughly. The ultrasound gel was applied before starting the exam. The examination was performed on both front legs using an ultrasound machine (VINNO 5 vet ultrasound scanner version 1.6.51.261, VINNO Corporation, Suzhou, China) with the 8-12 MHz linear array transducer (Smith and Cauvin, 2014).

Both longitudinal and cross-sectional areas were assessed for tendon damage and scored as the Fiber Alignment Score (FAS) and Echogenicity score from 0-3 (Hodgson et al., 2013) by a blinded sports medicine specialist veterinarian. The cross-sectional area (CSA) were measured by a veterinarian using the measurement mode of the ultrasound machine and recorded in square centimeters (cm^2). The biggest CSA level for diffuse tendinitis or mixed lesions and the most obvious core-lesion level were recoded.

Rehabilitation and follow up program

All the tendinitis-suffering ponies were treated with the same treatment protocol in the first 7 days. The first aid treatments started with giving Phenylbutazone by intravenously (Butasyl®: Zoetis) as the anti-inflammatory medicine (4.4 mg/kg in the first 3 days, then 2.2 mg/kg until day 7) along with ice booting 2 times a day at 20 minutes for each section. Throughout the study, the ponies in both treatment groups were subjected to the same rehabilitation program, as shown in Figure 2. The rehabilitation program is based on the details in Table 1. The lameness examinations, pain assessment and ultrasonography were performed on day 8, day 30, and day 60.

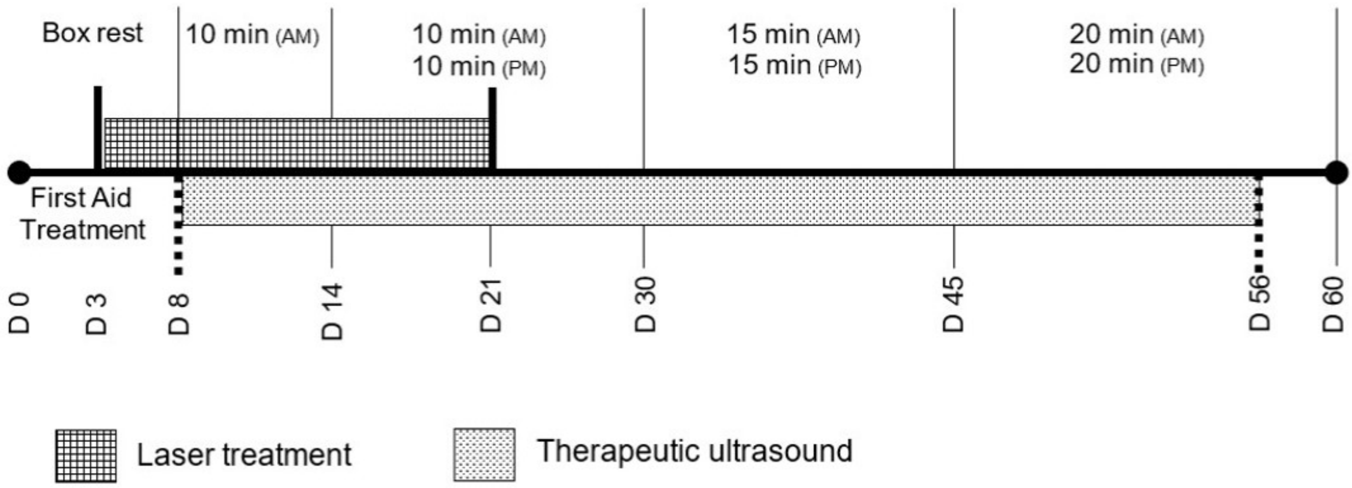

Figure 2 A schematic timeline of treatments and rehabilitation program. Beginning with a seven-day first-aid treatments, laser treatments (Day3-21), therapeutic ultrasound (Day8-56) and a rehabilitation program. D: Day, Min: minute, AM: Morning exercise, PM: Afternoon exercise.

Table 1 The rehabilitation program for polo ponies in this study (W; week)

Plan	Exercise
W1	Box rest
W2	Walk by hand 10 min a day
W3-4	Walk by hand 10 min 2 times a day
W 5-6	Walk by hand 15 min 2 times a day
W 7-8	Walk by hand 20 min 2 times a day

High-intensity laser therapy

The protocol of treatment was the SmartCoat settings and preset protocol of the diode laser machine (litecure Companion laser® CTC-12; Companion Animal Health, New castle, USA). The power was set at 12 W, continuous mode, wave length 980-810 nm and 9 minutes 40 seconds of treatment time. The hair was clipped and the treatment area was cleaned with 70% alcohol before starting the treatment. The ponies were confined in the stall without sedative medicine during the treatment. The treatment started on day 3 of injury, and ten treatments were applied on the palmar of SDFT every 48 hours.

Therapeutic Ultrasound

The therapeutic ultrasound (SONIC vital XTcoloR: schwa-medico, Ehringshausen, Germany) used in this study was the dual frequency transducer; 1 and 3 MHz. The Effective Radiating Area (ERA) of treatment transducer is 4 cm^2 and Beam Nonuniformity Ratio (BNR) < 5.0. The adapted treatment protocol was divided into two sections. The first section started on day 8 of the initial injury using 3 MHz. In this phase, the ponies were treated twice weekly for six treatments, and then the protocol changed to the second section. The second section was performed once a week for four more treatments, using 1 MHz of the ultrasound frequency. The dosage details are shown in Table 2 (Kaneps, 2016).

The two treatment modalities were performed by the same two training veterinarians throughout the study.

Table 2 The dosage of 2 therapeutic ultrasound treatment sections

	Section 1 2 times a week	Section 2 1 time a week
Frequency	3 MHz	1 MHz
Intensity	1.0 W/cm^2	1.0 W/cm^2
Duty cycle	30%	100%
Timing	10 minutes	6 minutes

Statistical analysis

The cross-sectional area (CSA) of the affected structure was measured using the ultrasound machine measurement mode at the level of the most obviously damaged area and were recorded every follow up day in square centimeters; this was the mainstay to designate tendon healing. The data normality distribution was determined by Shapiro-Wilk test. One-way repeated ANOVA was used to test the CSA change within the treatment group and two-way mixed ANOVA was tested for the CSA change between treatment groups. The proportion test was used for analysis of the FAS and echogenicity score improvement. Spearman's rank correlation was used to test the relation between lameness and structure. All the data were analyzed by R program version 4.0.3 (R Foundation, Vienna, Austria).

RESULTS

There were 88 polo ponies who had been examined, of which 25 polo ponies were diagnosed to have tendinitis or desmitis; only 10 ponies were selected for this study. From the history, there are six ponies have been diagnosed with a new-tendon injury, while four others have a re-injury issue. Two of the 10 ponies were found to have bilateral forelimbs tendinitis, 5 ponies had lesions on the left front leg, and 3 ponies had lesions on the right front leg. Therefore, twelve limbs with tendinitis were studied.

Lameness results

On the first day of examination, eight ponies showed signs of lameness. Five of these 8 lame ponies were lame on the same side with the tendinitis problem, and 2 from these 5 lameness-inducing limbs were positive to flexion test when lameness examinations were performed. However, this study found that the SDF tendinitis did not relate to the lameness signs ($P = 0.2$) as well as a previous study (Pluim et al., 2018).

Ultrasonography

From the ultrasonography, there were 3 legs found to have both SDFT and SL problems, and 1 leg found to have both SDFT and DDFT problems. Most of the lesion effects were on levels 1B to 3A referring to the cross-sectional area of the tendon (Hodgson et al., 2013). Three from 12 limbs were considered to be core-lesion which one core-lesion limbs was random to HILT group and two core-lesion limbs were random therapeutic ultrasound group. The rest were considered to be diffuse tendinitis. Evaluating the echogenicity score, there were 3 limbs with mild lesions, 3 limbs with moderate lesions, and 6 limbs with severe lesions on the first day. However, after the 60-day follow up, the severity of the echogenicity did not significantly change during this study ($P > 0.9$) (Figure 3). The cross-sectional area (CSA) was measured from the cross-sectional view and the results show that the average tendinitis tendon size was 1.28 cm^2 (95% CI 1.14-1.42) which is 20% bigger than the contra-lateral side (1.05 cm^2; 95% CI 0.85-1.26). The CSA after treatment with HILT and therapeutic ultrasound showed that at day 8 of initial injury, there was one tendon in each group with a 10% smaller CSA than the first day. Two ponies in each group had a 10% smaller CSA on day 30. Moreover, the result show that on the last day of follow up, two tendons had a 20% smaller CSA compared to the first day in therapeutic ultrasound group, and one tendon had the same reduction in the HILT group. However, the tendon size did not significantly change from the first to the last check within (HILT: $P = 0.2$; therapeutic ultrasound $P > 0.9$) and between treatment group ($P > 0.9$) (Figure 4). Longitudinal assessment of the tendon showed alignment of the tendon fibers as the 60-day follow up of the fiber alignment had not significantly changed at any time point ($P > 0.9$) (Figure 5).

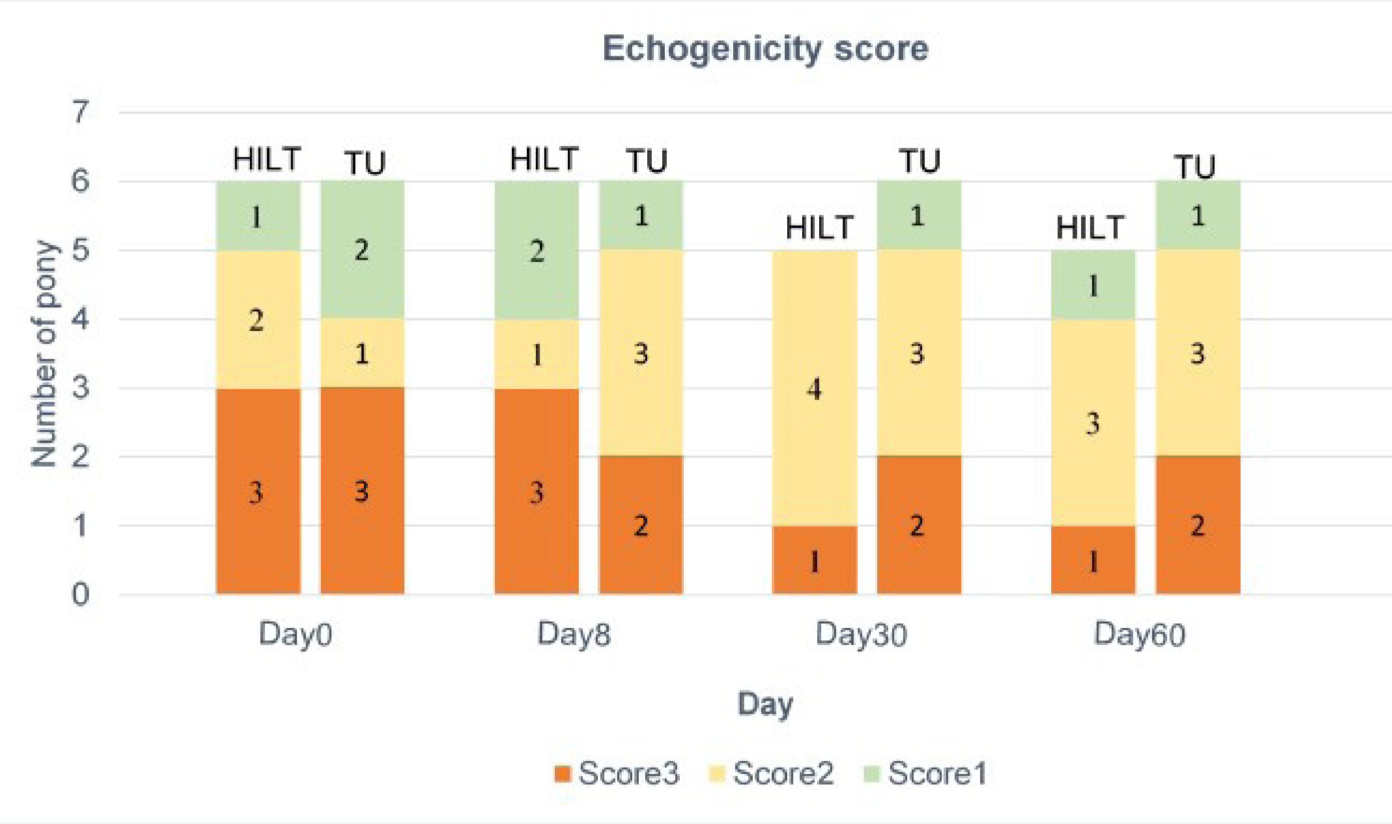

Figure 3 The number of the ponies in each echogenicity score compared from the first day until day 60 of following high-intensity laser therapy (HILT) and therapeutic ultrasound (TU).

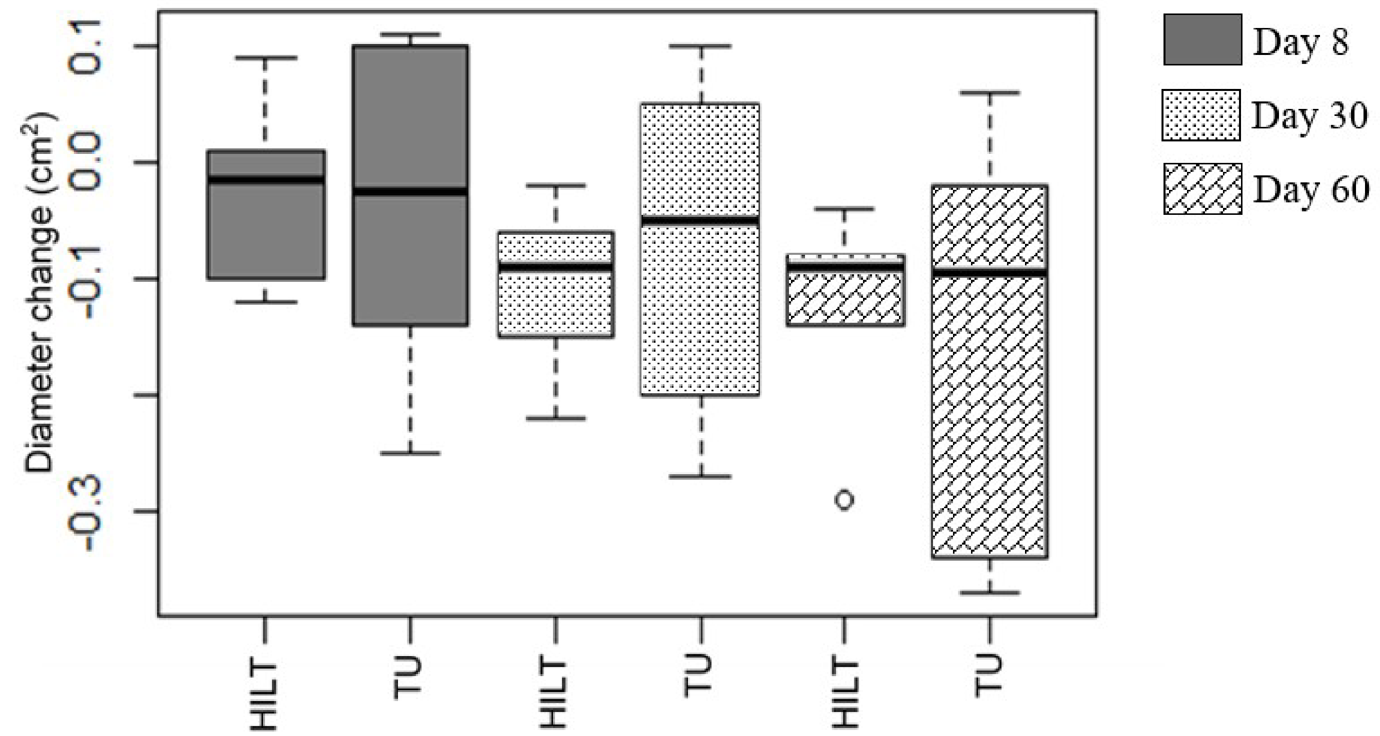

Figure 4 The CSA change after 3 follow-ups in both groups of treatment shown to have no significantly change (HILT: $p = 0.2$; TU: $P > 0.9$), high-intensity laser therapy (HILT) and therapeutic ultrasound (TU).

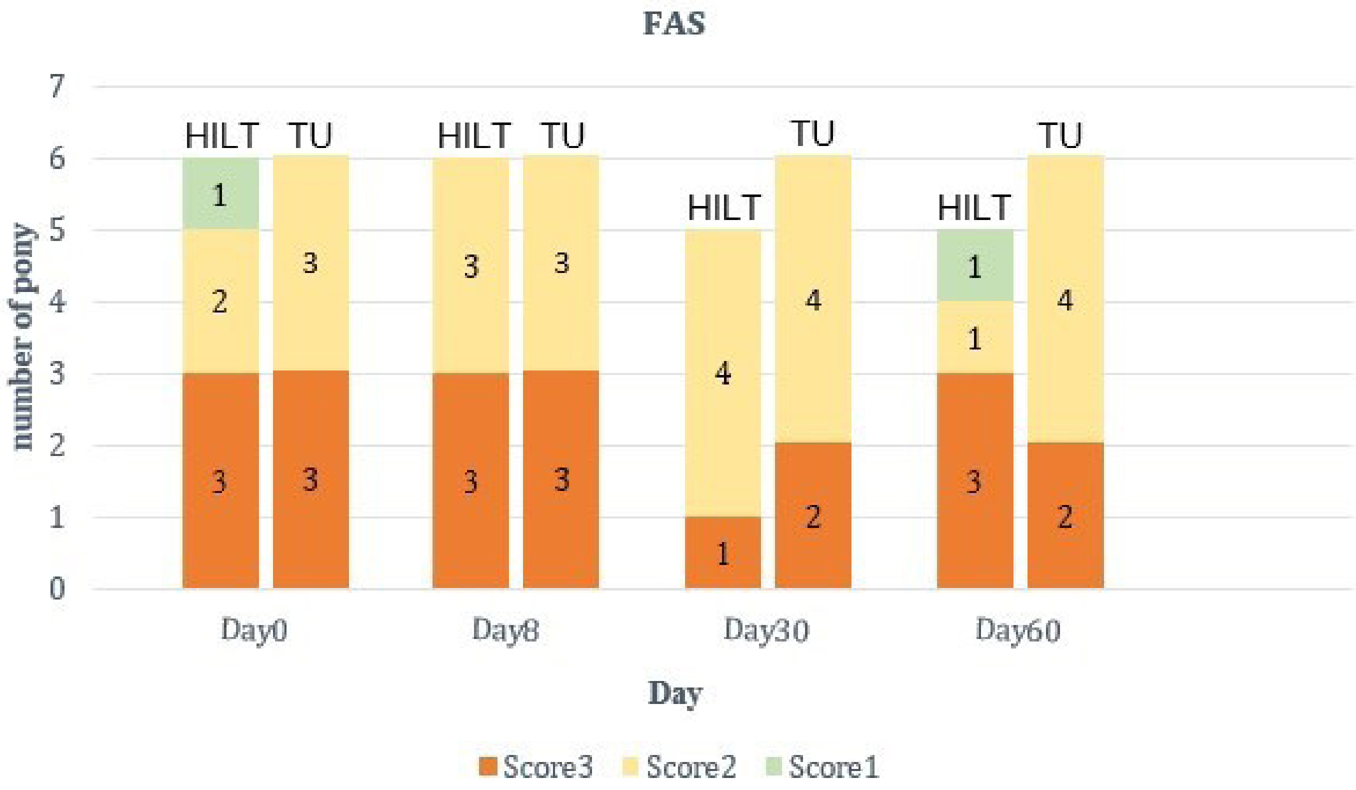

Figure 5 The number of the ponies in each FAS severity score compared from the first day until day 60; high-intensity laser therapy (HILT) and therapeutic ultrasound (TU).

DISCUSSION

Referring to the evidence from this result, the left front leg was more affected than the right front leg and some ponies showed signs of tendinitis on both legs. That was not related to style of using of the ponies in this club as they were taken to the exercise track twice a day for 1 hour each for exercise. The 1-hour exercise consisted of three equal sections: walk, trot, and walk. In the trot phase, a ridden pony was cantered by a rider in right-lead to lead the others in each rider group (1 group consisted of 1 ridden pony and 3-4 handled ponies) to trot in the same time. The speed of the trotting phase was about 4.7 m/s for 20 minutes. Moreover, during the polo game, right-lead canter is still the main stride as well. However, this supports the previous study that the intensity and the duration of the exercise do not affect the evidence of tendinitis (Birch et al., 2008). There are many factors prone to increase the risk of tendinitis such as sudden weight loading, on the left side of the body when the players get on or jump on the horse back, time and style of bandaging (Snively et al., 2015), shoeing, and track and polo field surface. These all can increase tendinitis rate in horses.

Due to the age and type of injury being mixed, that might affect the healing rate due to the accumulation of micro-damage in the extracellular matrix (ECM) and scar tissue. The researcher separated the ponies' ages into mature middle-aged ponies, aged 5–13 years, and middle-aged to senior ponies, aged 14–20 years. There is one pony in therapeutic ultrasound treatment who was considered to be in the middle-aged to senior group. Considering the type of lesion, the results showed that only one pony with a re-injured tendon improved after therapeutic ultrasound treatment. Two of three re-injury ponies were not control in the rehabilitation exercise program. Another had more than two re-injuries of the same tendon. However, Tamura et al., 2018 and Pluim et al., 2018 found that the age does not affect the healing rate of tendinitis cases when compared with the different treatment modalities. Regarding the tendon cell's synthetic activity after injury, the function and reducing cellularity does not relate with different ages after tendon maturity. However, ageing is more involve to the injury rate in older horse (Thorpe et al., 2016 and Ribitsch et al., 2020). On the other hand, the quality of the tendon tissue on the first examination means that none of the re-injured tendons have a noticeably scarred accumulation at the current injury level but appear on the diffuse hyperechogenic line. However, since tendon scar tissue accumulated has yet to be scored, the healing behavior in diffuse and core-lesion tendinitis and the re-injury rate have to be studied further.

Due to polo ponies are high performance horses, multi-structural injuries can be found commonly. Interpreting the lameness results from the initial sensor system showed that two ponies had only one front leg lameness while the other eight ponies experienced combined forelimb and hind limb lameness (Reed et al., 2020). Thus, since nerve blocking and intra-articular anesthesia were not included in this study protocol, the researchers could not identify the source of lameness. Therefore, using lameness as the tendon function assessment tool after SDF tendinitis is ineffective in high sport-performance horses and requires more specific tests to evaluate tendon function.

The CSA of one pony in the therapeutic ultrasound group got up to 10% bigger on day 8 of treatment. This could have resulted from protease enzymes working during the first phase of injury (Goodrich, 2011). This same result happened in a previous study (Birch et al., 2008) of HILT for tendinitis treatment. The researchers do not recommend using the FAS as one of the indication methods to evaluate the efficiency of the tendinitis treatment at the short-time follow up due to this criteria having a rough scale measured subjectively; a small change will not affect the score as shown in the results. The CSA measurement from the ultrasound machine is a more objective tool to access tendon over usage or inflammation by increasing of the CSA. In contrast, decreasing of the CSA can indicate the tendon responsiveness to inflammation treatment as well. From day 8 to day 30, the CSA change in the HILT group (Figure 4) shows a clear decrease. These findings indicate that our laser treatment protocol can inhibit and clam down the inflamed tendon during its early healing phase. However, the CSA seems to stabilize between days 30 and 60, which is the non-treatment period and the chronic remodeling phase of the tendon. Therefore, the longer laser treatment period and frequent monitoring by the CSA change and pain score have to be further study. Nevertheless, there is still an impact from human error to measure the CSA, so this tool can evaluate as a semi-objective measurement.

Two from three limbs in the HILT group did not change in the CSA. These two limbs were from the same ponies (bilateral forelimbs tendinitis), the other one was not controlled in the rehabilitation program. The same result in two ponies from the therapeutic ultrasound group that were not controlled the exercise rehabilitation and the CSA decreased less than 10% from the initial size. There was another tendon in therapeutic ultrasound group that did not change in the CSA size. It was found that tendon was a re-injury that had occurred more than twice recurrent in its history. However, there are one pony missing the ultrasonographic data on day 30 and one pony missing data on day 60 due to the travel limitation of the veterinarian who perform ultrasonography from COVID-19 outbreak situation. Which these 2 missing data might not affect the results.

There are some new studies of HILT with different treatment protocols that had the same effectiveness (Roberts et al., 2013; Pluim et al., 2018; Zielińska et al., 2020). Therefore, the treatment dose, the frequency, the speed of applying the laser and the duration of treatment should be considered for the further study. However, long-term follow up of tendon scar formation and re-injury rate should be considered.

No tissue reaction was found in both group of treatments. Furthermore, the HILT can be used with or without contact to the horse's leg, and no hair clipping is required. Nevertheless, the laser machine used in this study was the early generation of a class IV laser, which still requires awareness of the heat effect. None of the ponies in our study had tissue reaction from the treatment. Some of the black skin and dark coat legs avoided their leg from the laser transducer after half of the treatment time most likely due to the absorption of the laser on the hair and skin and resulting heat accumulating on the skin. For these horses, it is suggested to decrease the power of treatment or speed up applying the treatment with this model of the machine.

None of the ponies in the therapeutic ultrasound group reacted to the treatment procedure. According to the nature of sound waves, when using this treatment method, the treatment area needs to be clean and clear of hair. Moreover, a sufficient amount of ultrasound gel always needs to be applied during the procedure. The literature supports that the therapeutic ultrasound has ability to reduce fibrous scarring (Denoix et al., 2001; Watson and Lawrence, 2016), but long-term follow up should done to confirm this property, as well as with HILT. However, the therapeutic ultrasound machine is much cheaper than the laser machine. This short-term follow up showed that both treatments are effective to decrease the tendon size after inflammation.

As for the result of the CSA, the rehabilitation program used in this study did not show adverse effects, but for longer rehabilitation programs, researchers should adjust following the severity of lesions and the different style of polo training.

Since this study was limited by multiple variables. Firstly, the unpredictably of the natural occurring of superficial digital flexor tendinitis cases, treatment allocation and exercise control intervened by the uncontrol factors. These lead to low sample size in this study. Secondly, there is no control group (exercise alone) to compare the effect of the two treatment modalities using in this study. Therefore, this study cannot inform whether these two treatments are more effective than the control exercise alone. Nevertheless, bigger study sample size and control exercise alone are required.

CONCLUSION

Both high-intensity laser therapy and therapeutic ultrasound are safe to use as the tendinitis treatment of polo ponies. According to the short-term follow up, both treatments can be interchanged as there was no difference in decreasing inflammation and promoting the healing process. In addition, a good rehabilitation program is an important key of tendinitis treatment.

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AUTHOR CONTRIBUTIONS

A. Kidtiwong contributed to study design, data collecting, data interpretation and manuscript preparation.
P. Issariyodom contributed to assisted in data collecting.
K. Na Lampang contributed to study design, statistical analysis and interpretation.
U. Pirunsan contributed to guide the study design, supporting diagnostic equipment and data interpretation.
P. Rungsri contributed to study design, data collecting, supporting diagnostic equipment, data interpretation and preparation of the manuscript. The final version of the manuscript has been approved by all authors.

CONFLICT OF INTEREST

There is no conflict of interests has been declared in this study.

REFERENCES

Baker, K.G., Robertson, V.L. and Duck, F.A., 2001. A review of therapeutic ultrasound: Biophysical effects. Phys. Ther. 81, 1351-8.

Baxter, G.M. and Stashak, T.S., 2011. Examination for Lameness: HISTORY, VISUAL EXAM, AND CONFORMATION. In: Baxter, G.M. (Ed.), Adams and Stashak's Lameness in Horses, 6th edn., Blackwell Publishing, Oxford, pp. 109-150.

Hodgson, D.R., McGowan, C.M. and McKeever, K., 2013. The athletic horse: principles and practice of equine sports medicine, 2nd edn., Elsevier Health Sciences, Missouri.

Birch, H.L., Wilson, A.M. and Goodship, A.E., 2008. Physical activity: does long-term, high-intensity exercise in horses result in tendon degeneration?. J. Appl. Physiol. 105, 1927-1933.

Costa-Paz, M., Aponte-Tinao, L. and Muscolo, D.L., 1999. Injuries to polo riders: a prospective evaluation. Br. J. Sports Med. 33, 329-31.

Demir, H., Menku, P., Kirnap, M., Calis, M. and Ikizceli, I., 2004. Comparison of the effects of laser, ultrasound, and combined laser + ultrasound treatments in experimental tendon healing. Lasers in Surgery and Medicine: The Official Journal of the American Society for Laser Medicine and Surgery. 35, 84-89.

Denoix, J.M., Pailloux, J.P. and Lewis, J., 2001. Physical therapy and massage for the horse, 2nd edn., Taylor&Francis group, Florida, pp. 131-138.

Dunn, F., Frizzell, L.A.,1990. Cryotherapy. In: Lehmann, J.F. (Ed.), Therapeutic Heat and Cold, 4th edn., Williams & Wilkins, Baltimore, pp. 398-416.
Farcic, T.S., Baldan, C.S., Cattapan, C.G., Parizotto, N.A., João, S. and Casarotto, R.A., 2013. Treatment time of ultrasound therapy interferes with the organization of collagen fibers in rat tendons. Braz. J. Phys. Ther. 17, 263-71.
Farcic, T.S., Baldan, C.S., Machado, A.F., Caffaro, L.A., Masson, I.F. and Casarotto, R.A., 2018. Collagen fibers in the healing process of rat Achilles tendon rupture using different times of ultrasound therapy. Adv. Wound Caref. 7, 114-20.
Geburek, F., Lietzau, M., Beineke, A., Rohn, K. and Stadler, P.M., 2015. Effect of a single injection of autologous conditioned serum (ACS) on tendon healing in equine naturally occurring tendinopathies. Stem. Cell Res. Ther. 6, 1-4.
Geburek, F., Gaus, M., Van Schie, H.T., Rohn, K. and Stadler, P.M., 2016. Effect of intralesional platelet-rich plasma (PRP) treatment on clinical and ultrasonographic parameters in equine naturally occurring superficial digital flexor tendinopathies–a randomized prospective controlled clinical trial. BMC Vet. Res. 12, 1-6.
Goodrich, L.R., 2011. Tendon and ligament injuries and disease. In: Baxter, G.M. (Ed.), Adams and Stashak's Lameness in Horses, 6th edn., Blackwell Publishing, Oxford, pp. 927-929.
Ho, J.O., Sawadkar, P. and Mudera, V., 2014. A review on the use of cell therapy in the treatment of tendon disease and injuries. J. Tissue Eng. 5, 1-18.
Inness, C.M. and Morgan, K.L., 2015. Falls and injuries to Polo players: risk perception, mitigation and risk factors. Sports Med.-Open. 1, 1-6.
Inness, C.M. and Morgan, K.L., 2015. Polo pony injuries: player-owner reported risk, perception, mitigation and risk factors. Equine Vet J. 47, 422-7.
Kaneps, A.J., 2016. Practical rehabilitation and physical therapy for the general equine practitioner. Vet. Clin. North Am. Equine Pract.. 32, 167-180.
Kasashima, Y., Takahashi, T., Smith, R.K., Goodship, A.E., Kuwano, A., Ueno, T. and Hirano, S., 2004. Prevalence of superficial digital flexor tendonitis and suspensory desmitis in Japanese Thoroughbred flat racehorses in 1999. Equine Vet. J. 36, 346-50.
Larkin, K.A., Martin, J.S., Zeanah, EH., True, J.M., Braith, R.W. and Borsa, P.A., 2012. Limb blood flow after class 4 laser therapy. J. Athl. Train. 47, 178-83.
Lipman, K., Wang, C., Ting, K., Soo, C. and Zheng, Z., 2018. Tendinopathy: injury, repair, and current exploration. Drug Des. Devel. Ther.12, 591-603.
Murray, R.C., Dyson, S.J., Tranquille, C. and Adams, V., 2006. Association of type of sport and performance level with anatomical site of orthopaedic injury diagnosis. Equine Vet J. 38, 411-6.
Tamura, N., Kodaira, K., Yoshihara, E., Mae, N., Yamazaki, Y., Mita, H., Kuroda, T., Fukuda, K., Tomita, A. and Kasashima, Y., 2018. A retrospective cohort study investigating risk factors for the failure of Thoroughbred racehorses to return to racing after superficial digital flexor tendon injury. Vet. J. 235, 42-46.
Pluim, M., Martens, A., Vanderperren, K., Sarrazin, S., Koene, M., Luciani, A., Van Weeren, P.R. and Delesalle, C., 2018. Short-and long term follow-up of 150 sports horses diagnosed with tendinopathy or desmopathy by ultrasonographic examination and treated with high-power laser therapy. Vet. Sci. Res. J. 119, 232-8.
Thorpe, C. T., McDermott, B. T., Goodship, A. E., Clegg, P. D. and Birch, H. L., 2016. Ageing does not result in a decline in cell synthetic activity in an injury prone tendon. Scand. J. Med. Sci. Sports. 26, 684-693.
Ribitsch, I., Gueltekin, S., Keith, M. F., Minichmair, K., Peham, C., Jenner, F. and Egerbacher, M., 2020. Age-related changes of tendon fibril micro-morphology and gene expression. J. Anat. 236, 688-700.
Reed, S.K., Kramer, J., Thombs, L., Pitts, J.B., Wilson, D.A. and Keegan, K.G., 2020. Comparison of results for body-mounted inertial sensor assessment with final lameness determination in 1,224 equids. J. Am. Vet. Med. A. 256, 590-9.
Roberts, D.B., Kruse, R.J. and Stoll, S.F., 2013. The effectiveness of therapeutic class IV (10 W) laser treatment for epicondylitis. Lasers. Surg. Med. 45, 311-7.
Santamato, A., Solfrizzi, V., Panza, F., Tondi, G., Frisardi, V., Leggin, B.G., Ranieri, M. and Fiore, P., 2009. Short-term effects of high-intensity laser therapy versus ultrasound therapy in the treatment of people with subacromial impingement syndrome: a randomized clinical trial. Phys. Ther. 89, 643-52.

Smith, R.K. and Cauvin, E.R., 2014. Ultrasonography of the metacarpus and metatarsus. In: Kidd, J.A, Lu, G.K, Frazer, M.L (Eds.), Atlas of equine ultrasonography, John Wiley & Sons, Oxford, pp. 73-105.

Snively, B.C., Bowser, J.E., Nabors, B. and Linford, R.L., 2015. The thermal effects of protective sports boots on the forelimb of Thoroughbred and Argentinian polo ponies. Equine Vet. Sci. 5, 393-394.

Thomopoulos, S., Parks, W.C., Rifkin, D.B. and Derwin, K.A., 2015. Mechanisms of tendon injury and repair. J. Orthop. Res. 33, 832-9.

United States Department of Agriculture, Animal and Plant Health Inspection Service., 2001. National Economic Cost of Equine Lameness, Colic and Equine Protozoal Myeloencephalitis (EPM) in the United States. 1-4

Watson, T., Lawrence, K., 2016. Electrophysical agents in animal physiotherapy. In: McGowan, C. and Goff, L (Ed.), Animal physiotherapy, 2nd edn., John Wiley & Sons, Oxford, pp. 212-224.

Williams, R.B., Harkins, L.S., Hammond, C.J. and Wood, J.L., 2001. Racehorse injuries, clinical problems and fatalities recorded on British racecourses from flat racing and National Hunt racing during 1996, 1997 and 1998. Equine Vet. J. 33, 478-86.

Witte, S., Dedman, C., Harriss, F., Kelly, G., Chang, Y.M. and Witte, T.H., 2016. Comparison of treatment outcomes for superficial digital flexor tendonitis in National Hunt racehorses. Vet. J. 216, 157-63.

Zielińska, P., Nicpoń, J., Kiełbowicz, Z., Soroko, M., Dudek, K. and Zaborski, D., 2020. Effects of high intensity laser therapy in the treatment of tendon and ligament injuries in performance horses. Animals. 10, 1327.

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