Pferdeheilkunde – Equine Medicine 38 (2022) 5 (September/October) 428–435 DOI 10.21836/PEM20220504

Results of a pilot study using serial ultrasonographic measurements of multifidus muscle in horses undergoing rehabilitation after medical or surgical treatment for overriding dorsal spinous processes

Richard P. C. Coomer[1], Maty G. P. Looijen[2], Ian G. Handel[3] and Shaun A. McKane[1]

[1] Cotts Equine Hospital, Robeston Wathen, Narberth, Pembrokeshire, United Kingdom
[2] Equine Referral Hospital, Royal Veterinary College, University of London, Hawkshead Lane, Hatfield, United Kingdom
[3] The Royal (Dick) School of Veterinary Studies and The Roslin Institute Easter Bush Campus, University of Edinburgh, Midlothian, United Kingdom

Summary: To assess whether cross-sectional area (CSA) of the equine multifidus muscle changed after treatment in horses with impinging and/or overriding dorsal spinous processes (ORDSP), 45 affected horses were recruited in a descriptive retrospective study. Before any treatment the CSA of the paired (left and right) multifidus muscles was measured by ultrasound at 3 levels: T15, T18 and L2. Horses underwent treatment: either by interspinous ligament desmotomy (ISLD, surgical) or by corticosteroid infiltration into the area of impingement (medical). All followed an exercise program before returning for repeat measurement. The effect of treatment on CSA following rehabilitation was assessed and compared statistically. Thirty-three horses underwent surgery and 12 medical treatment. Overall CSA increased after treatment at each site (percentage increases ranged from 9.6% to 32.3%) and the increase was significantly greater than zero at all sites except at L2 for the medical procedure. CSA change differed between sites with T15 having an 8.7% absolute greater increase than L2 ($P < 0.001$). Surgical horses had higher radiographic scores than medical (0.962 [95% CI 0.881–1.043] c.f. 0.424 [95% CI 0.329–0.518]) and also experienced a greater increase in CSA at all locations ($P < 0.001$), the greatest being 32.3% at T15. It was concluded that treatment of ORDSP led to an increase in multifidus CSA, considered to indicate improved spinal functional health. Serial measurement of multifidus CSA provided a useful objective means of assessing response to treatment.

Keywords: multifidus, horse, rehabilitation, dorsal spinous process

Citation: Coomer R. P. C., Looijen M. G. P., Handel I. G., S. McKane S. A. (2022) Results of a pilot study using serial ultrasonographic measurements of multifidus muscle in horses undergoing rehabilitation after medical or surgical treatment for overriding dorsal spinous processes. Pferdeheilkunde 38, 428–435; DOI 10.21836/PEM20220504

Correspondence: Maty G. P. Looijen, Equine Referral Hospital, Royal Veterinary College, University of London, Hawkshead Lane, Hatfield, AL9 7TA, United Kingdom; mlooijen@rvc.ac.uk

Submitted: April 12, 2022 | **Accepted:** July 12, 2022

Introduction

Back pain is commonly associated with poor performance in the equine athlete (*Cousty* et al. 2010, *Girodroux* et al. 2009, *Jeffcott* 1980). Although it can be attributed to various osseous and soft tissue pathologies, impingement or overriding of the dorsal spinous processes (ORDSP) is reportedly the most common cause (*Jeffcott* 1979, *Mayaki* et al. 2019, *Walmsley* et al. 2002). The condition can be managed medically, by rest and systemic non-steroid anti-inflammatory medication (NSAIDs) (*Denoix* and *Dyson* 2011, *Henson* and *Kidd* 2009). Alternatively, direct injection with corticosteroid anti-inflammatories (*Coomer* et al. 2014, *Coomer* et al. 2012, *Denoix* and *Dyson* 2011, *Henson* and *Kidd* 2009, *Walmsley* et al. 2002) or other analgesics including Sarapin Injection, either infiltrated locally or with by mesotherapy. Other methods are extra-corporeal shockwave therapy, acupuncture and physiotherapy (*Denoix* and *Dyson* 2011, *Henson* and *Kidd* 2009, *Trager* et al. 2020). Surgery is an alternative, either by ostectomy (*Desbrosse* et al. 2007, *Roberts* 1968, *Walmsley* et al. 2002), wedge ostectomy (*Brink* 2014, *Jacklin* et al. 2014) and interspinous ligament desmotomy (ISLD) (*Coomer* 2014, *Coomer* et al. 2012, *Derham* et al. 2019, *Prisk* and *García-López* 2019).

The multifidus muscle is known to play a major role in intervertebral stabilisation and proprioceptive adjustment of the spine (*Denoix* and *Dyson* 2011, Hideset al. 1996, *Roethlisberger Holm* et al. 2006, *Stubbs* et al. 2006). This muscle is a major stabiliser of the quadruped spine (*García Liñeiro* et al. 2017 and 2018, *Kaigle* et al. 1995) and its anatomy and function are comparable to that of man (*Rombach* et al 2014, *Stubbs* et al. 2006). Back pain causes dysfunction of the multifidus, leading to atrophy ipsilateral to the site of pain and thus asymmetry of the muscles in man (*Hides* et al. 1996) and horses (*Stubbs* et al. 2011). These studies support both the important role of the equine multifidus in spinal stabilisation and the use of ultrasonography as an objective diagnostic tool in equine back pain.

The purpose of this pilot study was to investigate whether treatment of ORDSP would have any effect on multifidus size. Two common treatment methods were used and our hypothesis was that multifidus muscle size would increase afterwards as a result of improved spinal function.

Materials and methods

Case selection

Horses were selected from amongst those presented for investigation of poor athletic performance and purported back pain, based on a combination of owner's, trainer's and referring veterinarian's assessments. The diagnosis of ORDSP was not based on local anaesthetic blocking owing to lack of riding facilities, though some were blocked and some had undergone scintigraphy before referral. A full clinical assessment was undertaken incorporating history taking, body assessment and palpation, followed by dynamic assessment at walk, trot and canter. Inclusion criteria were (1) a history of poor performance considered by the owner or trainer to be attributable to back pain; (2) radiographic evidence of ORDSP, and (3) absence of lameness at time of treatment.

Lateral radiographs were obtained with horses sedated using detomidine (0.01 mg/kg iv) and acepromazine (0.03 mg/kg iv), with or without butorphanol (0.01 mg/kg iv), depending on the temperament of the horse. Horses were positioned standing square with the head lowered, centering on the thoracolumbar and lumbar dorsal spinous processes, using a computed radiography system (a). All abnormal spaces were marked and graded using a 4-point scale (*Denoix* and *Dyson* 2011).

Ultrasound examination

Horses were restrained in stocks. Before any treatment was carried out, the 3 anatomical levels of T15, T18 and L2 were selected because they provided a repeatable and representative sample from each horse, whilst allowing measurements to be easily and quickly obtained. These sites were identified in all horses by reference to the abnormal spaces on radiographs and palpation. The 3 sites were marked with a horizontal patch in the hair using a #50 clipper blade, which helpfully remained visible at re-assessment.

Ultrasound examination was carried out using standard skin preparation with a 2–4 MHz phased array or 3–4 MHz curvilinear probe before treatment (b). Images of the left and right multifidus muscle was obtained with the probe oriented in the transverse plane, midway between adjacent facet joints level with the body of the vertebra, 4 to 5 cm lateral to midline on the parasagittal plane. The multifidus was identified by virtue of its multiple overlapping fascicles lying on the axial margin of the dorsal spinous process, lending it a well-defined echodense eccentric teardrop shape (Figure 1). Two images were obtained of each muscle at each of the 3 sites, left and right, giving a total of 12 images per horse per examination. Cross sectional area (CSA) was measured and recorded at the same time using software on the ultrasound machine, with values expressed in cm^2. If the 2 measurements at the same site differed more than 0.5 cm^2 at the time, a third image was obtained and the 2 closest measurements were recorded together with their mean for further calculation of change in multifidus area, MF. Owners gave informed consent for ultrasound assessment for the purposes of this study.

Treatment

The choice of subsequent treatment was led by severity of clinical and radiographic signs and owner preference. In all cases, skin was prepared aseptically and desensitised with 2% mepivicaine hydrochloride (1 ml). In medical horses, group MH, a 5 cm 19 g needle was advanced into or immediately adjacent to the affected space. Methylprednisolone acetate was injected, with a maximum dose of 40 mg/space and 160 mg per 500 kg horse, divided equally amongst the affected spaces (*Coomer* et al. 2012). Radiographic control was used in all cases. Horses undergoing surgical treatment, group SH, underwent ISLD as previously described (*Coomer* et al. 2012).

Exercise plan

Owners were instructed to perform daily 'Carrot stretches', belly lifts and other mobilising exercises designed to improve core strength and reactivate spinal musculature (*Harman* 2009, *Stubbs* et al. 2011). All horses followed a 4- to 6-week non-ridden exercise plan after treatment. Group SH underwent an initial 12-day period of box rest with small

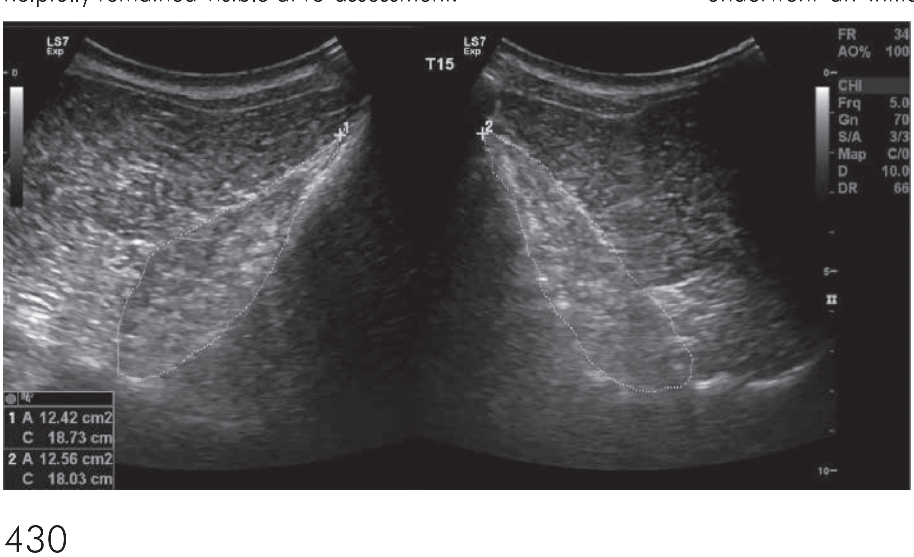

Fig. 1 Transverse ultrasound image taken to measure multifidus CSA at T15 in 1 horse, left side to the left. The multifidus can be identified as a characteristic echodense teardrop-shaped structure lying axially against the body of the dorsal spinous process.

paddock turnout after this time. A minimum of 30 minutes hand walking was recommended twice daily starting the day after surgery and continued up until week 4. Lunging work on 20 m circles wearing a postural aid, such as a Pessoa, was started in week 4 and increased every week. Group MH underwent 48 hours paddock turnout then followed a 3-week non-ridden exercise program identical to the second 3 weeks of SH. Some horses received supplementary treatment from physical therapists during their rehabilitation and this was recorded.

Reassessment

All horses underwent repeated physical passive and dynamic examination and ultrasound measurement at the end of their rehabilitation, typically 3–6 weeks after treatment. Ultrasound images were obtained using the still-visible clipper marks to ensure the exact same anatomical points of measurement were used. The CSA was measured in the same way and images stored.

Data collection and statistical analysis

Data were collated on a spreadsheet using Mircrosoft Excel (c) and a dedicated statistics programme (R Project) used for further tests and modelling (d). Data was tested for normality using the Kolmogorov-Smirnov test and differences in CSA tested using T-tests with time, anatomical location and side as fixed variables and horse as a random effect. Difference between groups in the pre-treatment CSA was also assessed using a mixed effects linear regression model including vertebral location as a fixed effect and horse as a random effect. Significance of procedure as a predictor of pre-treatment CSA was tested using a likelihood ratio test. Variables used in the models were: procedure (surgical or medical); vertebral location (T15, T18, L2); side (left or right), age, period between pre-treatment and post-treatment assessment (rehabilitation time), mean radiographic score over all locations (L1 to T18) and the pre-treatment baseline value calculated as a percentage difference from mean for all horses in the relevant treatment group at the corresponding vertebral location.

Results

Forty-five horses were treated. Mean age was 10, median 9, range 4 to 21 years. Twenty-one mares and 24 geldings were treated. Breeds were Thoroughbred and their crosses 14, Warmblood 13, Irish draft and crosses 8, Cob 4, Pony 3, Morgan 2 and Standardbred 1. Thirty-three horses underwent surgical treatment; 12 medical. First and second consecutive measurements taken on the same occasion did not differ significantly. Measurements of CSA on the left and right sides were not significantly different either, indicating no significant asymmetry, $P = 0.646$. The initial CSA of the 2 groups did not differ ($P = 0.19$), Table 1.

Horses returned for their second measurement at mean 48 days after the treatment. Differences in recommended rehabilitation between the groups meant that MH came back after a mean 26 days, versus 56 days for SH, $P = 0.005$.

Effect of radiographic grade

Counting only treated sites, mean radiographic grade/horse was 1.9 (range 1.0–3.1) and 1.4 (range 1.0–2.8) SH and MH, respectively $P = 0.012$. Horses with higher radiographic scores were more likely to be treated surgically (Figure 2 and 3): number of treated spaces in the SH group was 5.8, versus 3.8 for MH, $P = 0.0128$.

Despite differences in radiographic grade between groups, mixed effects modelling showed no evidence to indicate any form of association between radiographic grade and subsequent % increase in MF CSA.

Table 1 Mean cross sectional areas (CSA) of the multifidus muscle at 3 points for both groups before and after treatment. Groups were compared with each other at both time point using independent samples T test, and with themselves using a paired T test, * $P \leq 0.0001$

	Location of Measurement					
	CSA T15 L	CSA T15 R	CSA T18 L	CSA T18 R	CSA L2 L	CSA L2 R
Panel A: All horses (45)						
Before cm^2	12.10	11.94	15.32	15.02	19.05	18.64
After cm^2	14.88*	14.84*	18.57*	18.30*	21.74*	21.29*
Change %	23.0	24.3	21.2	21.8	14.1	14.2
Panel B: Surgery (33)						
Before cm^2	11.61	11.60	15.00	14.85	18.73	18.29
After cm^2	15.02*	15.18*	18.46*	18.26*	21.81*	21.75*
Change %	29.3	30.1	23.0	22.9	16.4	18.9
Panel C: Medical (12)						
Before cm^2	12.79	12.82	15.74	15.52	18.95	18.65
After cm^2	14.41	14.24	18.47	18.43	21.32	20.77
Change %	12.7	11.0	17.3	18.8	12.5	11.4

Multifidus changes

Total (sum T15+T18+L2) CSA increased significantly at all 3 spinal levels, rising from a mean 46 cm^2 to 55 cm^2, 19%, $P < 0.0001$ (Table 1/Figure 4). Individual locations exhibited differential growth, with greater changes further forwards and surgically treated horses demonstrating growth at all points, Table 1. In horses treated medically there was an association between longer rehabilitation times and a lower increase in CSA. Cross sectional area change was unrelated to rehabilitation time in surgical horses.

The best multivariable model estimating change in multifidus area included pre-treatment CSA, vertebral location and treatment procedure. There was evidence of a difference in CSA % change between vertebral sites (L2 8.7, SE 2.1, less than T15 reference $P < 0.001$). There was a negative association between pre-treatment CSA and CSA % increase after treatment (-0.895, SE 0.070, % post treatment CSA per % pre-treatment CSA $P < 0.001$), indicating that horses with lower CSA before treatment improved more after treatment. There was also evidence that the surgical group had a greater % increase at first measurement than the medical group (13.938, SE 5.646, $p = 0.014$). The estimated % increase in multifidus CSA from the mixed effects model are shown in table 2. Analysis of the available second post treatment measurements for 4 horses in each group showed a continuing trend for improvement (table 2 last column).

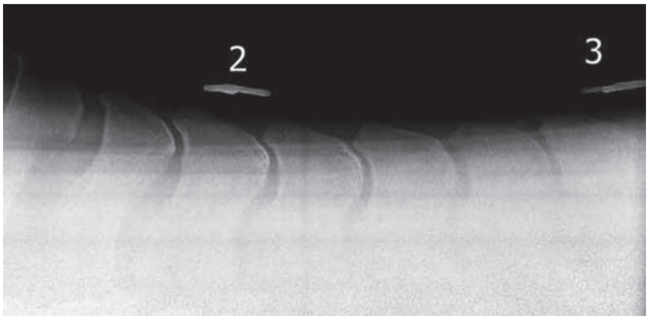

Fig. 2 Example of a lateral radiograph of mid to caudal thoracic spinous processes of a horse that underwent medical treatment. Mild to moderate radiographic changes are found of the spinous processes with remodelling and sclerosis and narrowing of the interspinous spaces. Cranial is to the left.

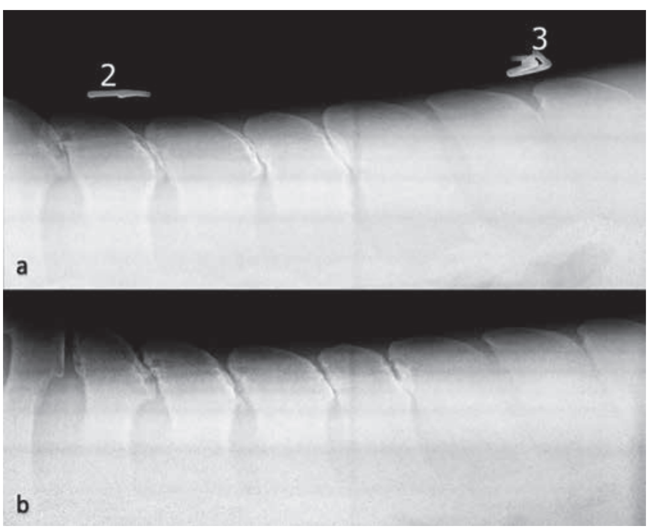

Fig. 3 Example of lateral radiographs of mid to caudal thoracic spinous processes of a horse that underwent surgical treatment, before (a) and after (b). Moderate radiographic changes are found of the spinous processes with remodelling, lysis, sclerosis and narrowing of the interspinous spaces. Postoperative changes show very mild widening of the interspinous spaces, however this may also be positional. Cranial is to the left.

Discussion

In this pilot study, treatment of ORDSP in clinical cases led to a significant increase in multifidus CSA bilaterally at each spinal level measured. Not all levels changed to the same extent, suggesting an association between treatment and rehabilitation for ORDSP and subsequent spinal muscle growth. This was previously observed but not objectively quantified (*Coomer* et al. 2012). Although limited by selection bias, our results suggest that there may be a tendency to 'reversion to mean': horses with an unusually small CSA before treatment improved more; less abnormal horses improved less. The multifidus plays a crucial role in stabilisation of the equine back, with segmental atrophy and asymmetry found in association with pathological changes at the same level (*Stubbs* et al. 2010). Although carried out post-mortem, that study demonstrated a strong association between the severity of pathological findings and degree of multifidus atrophy. Our study corroborated these findings, since the highest radiographs scores were associated with the smallest starting CSAs, typically in horses treated surgically. Despite this, we were unable to demonstrate any association with severity of radiographic grade and percentage increase in CSA, most likely owing to bias problems with case selection. The amount of improvement seemed more likely to be related to the chro-

Table 2 Estimated mean percentage increase at each vertebral location for medical and surgical treatment horses at first assessment; further percentage increases were also evident in the 4 horses from each group that were measured a second time, compared to time 0 (right hand column).

Procedure	Vertebra	% Increase CSA	SE	Lower 95% CL	Upper 95% CL	% Increase CSA at second assessment (n = 4)
medical	T15	18.4	5.0	8.4	28.4	16.066
surgical	T15	32.3	3.2	26.0	38.6	45.802
medical	T18	14.4	5.0	4.4	24.4	17.291
surgical	T18	28.3	3.2	22.0	34.6	59.390
medical	L2	9.6	5.0	-0.4	19.7	18.004
surgical	L2	23.6	3.2	17.2	29.9	78.169

nicity and degree of wastage at the outset, rather than treatment method. Therefore, it is important to consider that this study should not be used as an indicator for selection of treatment but as a guide on how to quantify improvement after either treatment chosen. Ideally, treatment would have been randomised to ensure a more even split of severities, however this was not feasible.

All horses in this study showed an increase in multifidus CSA after treatment, the largest in the thoracic spine, with increases in the lumbar spine less marked. This pattern was also seen in a previous study, where 'normal' horses considered free from back pain followed a 3-month exercise programme, with changes in measurement of multifidus CSA assessed at 6 thoracolumbar locations (*Stubbs* et al. 2011). We did not measure as far forward as T10, but several possible explanations exist for this apparent pattern of increased thoracic growth. T15 is located at the approximate midpoint of the thoracolumbar spine as supported by the 4 limbs, maximising interspinous pressure through dorsiflexion, especially under saddle. This would occur in all horses, whether or not they have ORDSP. The mid to caudal thoracic region is also most commonly affected by ORDSP (*Clayton* and *Stubbs* 2016, *Cousty* et al. 2010, *Jeffcott* 1980). Horses with back pain, most with ORDSP, exhibited reduced range of dorsoventral flexion extension in this area, yet showed no such changes in the lumbar spine (*Wennerstrand* et al. 2004). This difference is likely to cause reduced muscle development in the dysfunctional area. Therefore, when muscles were re-activated during treatment, this area is likely to have had the most to regain.

It has been shown that the interspinous region is richly innervated with sensory nerve fibres (*Ehrle* et al. 2017) and that horses affected by ORDSP have increased density of sensory nerves in the area of impingement (*Ehrle* et al. 2019). If treatment and rehabilitation of horses with ORDSP successfully resolves pain, it seems logical that this would lead to increased use and hence muscle development. In this pilot study, horses treated with ISLD had higher radiographic scores than those treated medically, meaning that the results cannot be compared. Medically treated horses showed a weaker association between longer rehabilitation times and a lower increase in CSA, yet no relationship was seen in surgical patients. It is unknown whether muscle growth is linear over time, or whether it slows and then ceases once a training stimulus limit, or a theoretical maximum size, is achieved. If such a limit exists, the control group may have been closer to it at the start, making total growth potential less in that group. Measuring the outcome of groups at the same time would have been optimal if direct comparison was the aim, but was not feasible within the logistic constraints of a clinical study of this type. Further research with a greater number of sampling periods is warranted.

Even after the resolution of the inciting cause of back pain in man, without physiotherapeutic interventions to restore size and function, the multifidus remains dysfunctional and atrophied, whilst back pain can persist *Hides* et al. 2001, *Hides* et al. 2008). All horses in this study followed a similar active rehabilitation plan, the only difference being a period of 3 weeks at the start designed to allow ISLD incisions to heal. Although identical exercise plans were supplied, it was left to the owner's discretion to follow the plan, thereby providing an additional source of variation. Furthermore, whether or not supplementary treatment by physical or manual therapists was carried out was not recorded, even though this can be beneficial (*Gómez Álvarez* et al. 2008, *Sayers* and *Tabor* 2020). It was not possible to accurately determine which horses in this study underwent supplementary treatment by a physiotherapist. Following an active post-treatment exercise regime to restore spinal function should be considered mandatory; whether supplementary physiotherapy gives additional benefit would be helpful for future study.

Conclusion

As we had hypothesised, the multifidus muscle showed significant increases in size in response to both treatments. The amount of improvement seemed more likely to be related to the chronicity and degree of wastage at the outset, rather than treatment method. Measuring equine multifidus CSA as a routine part of a post-treatment assessment provided an objective means of gauging changes in spinal health in response to

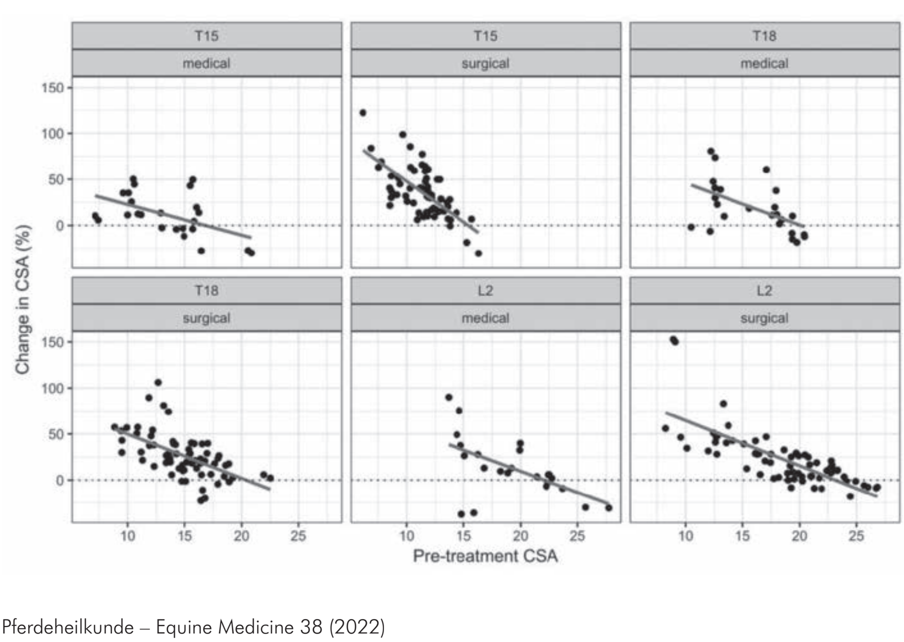

Fig. 4 Change in MF CSA between pre-treatement measurement and first post-treatment measurement for medically and surgically treated horses vs pre-treatment CSA including linear best fit smoother

the therapeutic interventions described. Further more strictly controlled studies are warranted to investigate the underlying mechanisms.

Manufacturer's addresses

a. Agfa Impax 1000, Agfa HealthCare Ltd, Vantage West, Great West Road, Brentford, Middlesex, TW8 9AX.
b. LOGIQ S7, GE Healthcare Ltd, Nightingales Lane, Chalfont St Giles, Buckinghamshire, HP8 4SP, UK.
c. Microsoft Excel 2007, Microsoft Corporation, One Microsoft Way, Redmond, WA 98052–6399, USA
d. R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.
e. Hadley Wickham (2017). tidyverse: Easily Install and Load 'Tidyverse' Packages. R package version 1.1.1. https://CRAN.Rproject.org/package = tidyverse
f. Douglas Bates, Martin Maechler, Ben Bolker, Steve Walker (2015). Fitting Linear Mixed-Effects Models Using lme4. Journal of Statistical Software, 67 (1),1–48. DOI 10.18637/jss.v067.i01.

References

Brink P. (2014) Subtotal ostectomy of impinging dorsal spinous processes in 23 standing horses. Vet. Surg. 43, 95–98; DOI10.1111/j.1532–950X.2013.12078.x

Clayton H. M., Stubbs N. C. (2016) Enthesophytosis and Impingement of the Dorsal Spinous Processes in the Equine Thoracolumbar Spine. J. Equine Vet. Sci. 47, 9–15; DOI 10.1016/j.jevs.2016.07.015

Coomer R. P. C., Fowke G. S., McKane S. A. (2014) Interspinous ligament desmotomy superior to corticosteroid medication to treat kissing spines: a prospective controlled study in 173 horses with long-term follow-up. Proceedings of American College of Veterinary Surgery E159

Coomer R. P. (2014) Desmotomy of the Interspinous Ligament in Standing Sedated Horses to Treat Kissing Spines: 142 Horses. Proceedings of European Collega of Veterinary Surgery, 34–37

Coomer R. P. C., McKane S. A., Smith N., Vandeweerd J. M. E. (2012) A controlled study evaluating a novel surgical treatment for kissing spines in standing sedated horses. Vet. Surg. 41, 890–897; DOI 10.1111/j.1532-950X.2012.01013.x

Cousty M., Retureau C., Tricaud C., Geffroy O., Caure S. (2010) Location of radiological lesions of the thoracolumbar column in French trotters with and without signs of back pain. Vet. Rec. 166, 41–45; DOI 10.1136/vr.c70

Denoix J.-M. M., Dyson S. J. (2011) Thoracolumbar spine. In *M. W. Ross & S. J. Dyson* (Eds.), Diagnosis and Management of Lameness in the Horse (2nd ed.), WB Saunders, 592–605; DOI 10.1016/C2009-0-50774-X

Derham A. M., O'Leary J. M., Connolly S. E., Schumacher J., Kelly G. (2019) Performance comparison of 159 Thoroughbred racehorses and matched cohorts before and after desmotomy of the interspinous ligament. Vet. J. 249, 16–23; DOI 10.1016/j.tvjl.2019.05.004

Desbrosse F. G., Perrin R., Launois T., Vandeweerd J. M. E., Clegg P. D. (2007) Endoscopic resection of dorsal spinous processes and interspinous ligament in ten horses. Vet. S. 36, 149–155; DOI 10.1111/j.1532-950X.2007.00247.x

Ehrle A., Ressel L., Ricci E., Merle R., Singer E. R. (2019) Histological examination of the interspinous ligament in horses with overriding spinous processes. Vet. J. 244, 69–74; DOI 10.1016/j.tvjl.2018.12.012

Ehrle A., Ressel L., Ricci E., Singer E. R. (2017) Structure and Innervation of the Equine Supraspinous and Interspinous Ligaments. J. Vet. Med. Series C Anatom. Histolog. Embryolog. 46, 223–231; DOI 10.1111/ahe.12261

García Liñeiro J. A., Graziotti G. H., Rodríguez Menéndez J. M., Ríos C. M., Affricano N. O., Victorica C. L. (2017) Structural and functional characteristics of the thoracolumbar multifidus muscle in horses. Anatomy 230, 398–406; DOI 10.1111/joa.12564

García Liñeiro J. A., Graziotti G. H., Rodríguez Menéndez J. M., Ríos C. M., Affricano N. O., Victorica C. L. (2018) Parameters and functional analysis of the deep epaxial muscles in the thoracic, lumbar and sacral regions of the equine spine. Anatomy 233, 55–63; DOI 10.1111/joa.12818

Girodroux M., Dyson S., Murray R. (2009) Osteoarthritis of the thoracolumbar synovial intervertebral articulations: Clinical and radiographic features in 77 horses with poor performance and back pain. Equine Vet. J. 41, 130–138; DOI 10.2746/042516408X345099

Gómez Álvarez C. B., L'Ami J. J., Moffatt D., Back W., van Weeren P. R. (2008) Effect of chiropractic manipulations on the kinematics of back and limbs in horses with clinically diagnosed back problems. Equine Vet. J. 40, 153–159; DOI 10.2746/042516408X250292

Harman J. (2009) Integrative Therapies in the Treatment of Back Pain. In *F. M. D. Henson* (Ed.), Equine Back Pathology, Blackwell Publishing, 235–248

Henson F. M. D., Kidd J. A. (2009) Overriding Dorsal Spinous Processes. In *Frances M.D. Henson* (Ed.), Equine back pathology: Diagnosis and treatment, Wiley-Blackwell,147–156

Hides J., Richardson C., Jull G. (1996) Multifidus muscle recovery is not automatic after resolution of acute, first episode low back pain. Spine 21, 2763–2769

Hides J. A., Jull G. A., Richardson C. A. (2001). Long-term effects of specific stabilizing exercises for first-episode low back pain. Spine 26, 243–248

Hides J., Gilmore C., Stanton W., Bohlscheid E. (2008) Multifidus size and symmetry among chronic LBP and healthy asymptomatic subjects. Man. Therapy 13, 43–49; DOI 10.1016/j.math.2006.07.017

Jacklin B. D., Minshall G. J., Wright I. M. (2014) A new technique for subtotal (cranial wedge) ostectomy in the treatment of impinging/overriding spinous processes: Description of technique and outcome of 25 cases. Equine Vet. J. 46, 339–344; DOI 10.1111/evj.12215

Jeffcott L. B. (1979) Back Problems in the Horse – A look at past, present and future progress. Equine Vet. J. 11, 129–136; DOI 10.1111/j.2042-3306.1979.tb01324.x

Jeffcott L. B. (1980) Disorders of the thoracolumbar spine of the horse – a survery of 443 cases. Equine Vet. J. 12, 197–210; DOI 10.1111/j.2042-3306.1980.tb03427.x

Kaigle A. M., Sten M. S., Holm H., Hansson T. H. (1995) Experimental Instability in the lumbar spine. Spine 20, 421–430

Mayaki A. M., Intan-Shameha A. R., Noraniza M. A., Mazlina M., Adamu L., Abdullah R. (2019) Clinical investigation of back disorders in horses: A retrospective study (2002–2017). Vet. World 12, 377–381; DOI 10.14202/vetworld.2019.377-381

Prisk A. J., García-López J. M. (2019) Long-term prognosis for return to athletic function after interspinous ligament desmotomy for treatment of impinging and overriding dorsal spinous processes in horses: 71 cases (2012–2017). Vet. Surg. 48, 1278–1286; DOI 10.1111/vsu.13298

Roberts E. J. (1968) Resection of thoracic and lumbar spinous processes for relief of pain responsible for lameness and some other locomotory disorders in horses. Proceedings of American Association of Equine Practitioners, 14, 13–30

Roethlisberger Holm K., Wennerstrand J., Lagerquist U., Eksell P., Johnston C. (2006) Effect of local analgesia on movement of the equine back. Equine Vet. J. 38, 65–69; DOI 10.2746/042516406775374351

Rombach N., Stubbs N. C., Clayton H. M. (2014) Gross anatomy of the deep perivertebral musculature in horses. Am. J. Vet. Res. 75, 433–440

Sayers E., Tabor G. (2020) An exploration of clinical reasoning and practices used by physiotherapists in the rehabilitation of horses following interspinous ligament desmotomy surgery. Physioth Theory Pract 25, 1–11

Stubbs N. C., Hodges P. W., Jeffcott L. B., Cowin G., Hodgson D. R., Mcgowan C. M. (2006) Functional anatomy of the caudal thoracolumbar and lumbosacral spine in the horse. Equine Vet. J. 3 (Suppl. 36), 393–399; DOI 10.1111/j.2042-3306.2006.tb05575.x

Stubbs N. C., Kaiser L. J., Hauptman J., Clayton H. M. (2011) Dynamic mobilisation exercises increase cross sectional area of musculus multifidus. Equine Vet. J. 43., 522–529; DOI 10.1111/j.2042-3306.2010.00322.x

Stubbs N. C., Riggs C. M., Hodges P. W., Jeffcott L. B., Hodgson D. R., Clayton H. M., Mc Gowan C. M. (2010) Osseous spinal pathology and epaxial muscle ultrasonography in Thoroughbred racehorses. Equine Vet. J. 42 (Suppl. 38), 654–661; DOI 10.1111/j.2042-3306.2010.00258.x

Trager L. R., Funk R. A., Clapp K. S., Dahlgren L. A., Werre S. R., Hodgson D. R., Pleasant R. S. (2020). Extracorporeal shockwave therapy raises mechanical nociceptive threshold in horses with thoracolumbar pain. Equine Vet. J. 52, 250–257; DOI 10.1111/evj.13159

Walmsley J. P., Pettersson H., Winberg F., McEvoy F. (2002) Impingement of the dorsal spinous processes in two hundred and fifteen horses: Case selection, surgical technique and results. Equine Vet. J. 34, 23–28; DOI 10.2746/042516402776181259

Wennerstrand J., Johnston C., Roethlisberger Holm K., Erichsen C., Eksell P., Drevemo S. (2004) Kinematic evaluation of the back in fully functioning riding horses. Equine V. J. 36, 495–498; DOI 10.2746/0425164044877431