# Outcome measures and their importance for effective equine back pain rehabilitation

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## Abstract

Effective rehabilitation for equine back pain is required due to the frequency of dysfunction effecting performance and welfare. Reliable and valid measures should be used establish a baseline in pain and dysfunction levels, and used to monitor change during rehabilitation, as well as support future research assessing the efficacy of treatment interventions. Such measures are collectively known as outcome measures and can include specific objective markers of impairments such as reduced range of motion, or pain on palpation. The aim of this narrative review is to discuss the options and tools available to use as outcome measures in relation to the treatment and rehabilitation of back pain in the horse. In this paper outcome measures critically discussed relate to conformation and standing posture, muscle dimensions, palpation, range of motion, objective gait analysis, functional analysis, owner reported outcome measures and pain scales. Recommendations are made to assist with selection of a suitable outcome measure. In conclusion, complex laboratory-based analysis systems are available to be gold-standard truly objective systems, although realism for clinical practitioners working in the field limits their use. There is a requirement for new outcome measures that are not subject to observer bias nor time or financially consuming, however it is possible to use those available currently with assist in clinical decision making for the benefit of the horse.

Key words: objective measurement, horse, spinal dysfunction, physiotherapy

## 1. Introduction

Equine thoracolumbar pain is reported to occur frequently, influencing their welfare and affecting athletic performance in ridden horses [1]. Combined data from multiple studies demonstrate that impingement of the dorsal spinous process is the most common finding in horses with and without clinical signs of back pain, with most pathology between the 14$^{th}$ thoracic and 2$^{nd}$ lumbar vertebrae [2-6]. Clinical signs of back pain can vary, however presentations to veterinarians for examination tend to be for behavioural change including overall poor performance, bucking or more subtle changed to the way the horse feels when ridden, resistance to saddling and vague, ill-defined lameness [4, 6-10]. On physical examination, there may be epaxial muscle spasm, atrophy and weakness, tenderness on palpation of the spinous processes and hypomobility of the thoracic spine, such as reduced flexion, extension, and lateral movement [9]. Clinically both hypo-and hyper-responsiveness can be appreciated in the musculature, often varying with chronicity and whilst there may be hypomobility as a response to hypertonic epaxial muscles, there may be exaggerated responses in a horse with an acutely painful thoracolumbar region.

As well as thoracolumbar osseous pathology, back pain can arise from primary issues such as poor saddle fit causing muscle pain [11], or secondary to pathology elsewhere in the horse, causing lameness, alteration of spinal kinematics and subsequent back pain [8]. Horses may present with clinical signs of both lameness and back pain and to understand this relationship further Landman *et al.* [8] studied a group of horses presented with orthopaedic problems (n=805) and a control group of horses undergoing pre-purchase examination that were considered free from problems (n=399). Whilst mild lameness was found in 19.5% of the control population, nearly 80% of the horses undergoing orthopaedic assessment were lame and 74.2% of those presenting with back pain were lame. This relationship has been studied in vivo showing that horses with induced back pain had altered spinal kinematics when in walk and trot on a treadmill, with the caudal thoracic region being more extended at both gaits [12]. In horses with induced lameness there was an alteration to the thoracolumbar range of motion pattern suggested to be the horse's method to reduce loading the lame limb by moving the centre of gravity [13,14]. Changes to spinal and limb kinematics in the presence of lameness or back pain respectively, as well as the imaging data showing presence of pathology with or without clinical signs highlight the complexity of interpreting clinical signs. Therefore, a combination of clinical examination and diagnostic aids such as nerve blocks and diagnostic imaging is often needed to identify the cause of the pain [15,16]. However, even with clinical examination and diagnostic imaging modalities, the underlying aetiology of back pain is often poorly defined [17]. Limitations to appreciating the aetiology, and thus diagnosis can be a result of underestimating co-existing osseous pathologies such as dorsal spinous process impingement, articular process remodelling, facet ankylosis or sacroiliac disease [18,19].

Following examination, diagnostic procedures and subsequent intervention the horse needs to be guided through a rehabilitation process to maximise function. In a recent survey of equine veterinarians in the United States, half recommended rehabilitation before surgery and two-thirds recommended rehabilitation after surgery, plus 82% reported that the clinical signs of back pain had improved with rehabilitation alone [20]. Therefore, rehabilitation is recommended to optimise function and welfare whether the goal is elite competition, leisure activities or for it to be unridden but 'field-sound'. A thorough understanding of the pathogenesis of back pain is essential to inform decision making during rehabilitation [21]. Plus knowledge of functional requirements for the expected outcome to inform goal setting is also important, as rehabilitation for a horse that competes in international eventing are different to a horse that is ridden on trails/hacked short distances. Irrespective of the intended outcome, to be able to judge effectiveness of back pain rehabilitation, measurement of factors that are influenced by the condition and subsequent intervention should be used [22]. Progressing through rehabilitation can be judged subjectively on the horse's ability to complete functional task such a tolerance to being ridden, in terms of behavioural aspects, or more quantitative constructs such as the number of raised poles the horse can successfully travel over before knocking them. Subjectively signs of improvement may be determined through observed posture changes and size or shape of the epaxial muscles, however subjective assessments may not be reliable.

Observer bias is inherent and a risk to the reliability in recording measurements and changes as a result of interventions and thus the truth of the effects of treatment [23]. Scientists, and practitioners often have strong expectations about the outcome of an experiment, even if they are not consciously aware of them [24] which means effects can be exaggerated especially if positive outcomes are desired. To reduce systematic discrepancy, masking observers and including a matched placebo intervention in research studies reduces risk of bias. However, in clinical practice robust randomised controlled studies are not undertaken within daily practice. Therefore, it is important to recognise the challenge in employing measurement outcomes and the potential for an observer to be influenced by bias [24] and measures that are objective should be used [25]. Ideally, reliable and valid measures should establish a baseline in pain and dysfunction levels, and used to monitor change during rehabilitation, as well as support future research assessing the efficacy of treatment interventions. Such measures are collectively known as outcome measures and can include specific objective markers of impairments such as reduced range of motion, or pain on palpation.

In human medicine outcome measures are frequently employed to gauge treatment effectiveness and efficiency [26]. Use of the Victorian Institute of Sport assessment outcome measure (VISA-OM) for the common over-use injuries of patellar and Achilles tendinopathy, has allowed authors to review studies comparing two exercise approaches to their management [27]. The VISA-OM scores symptoms, simple tests of function and the ability to play sport using a visual analogue scale from 0-10 [28,29] and has been used successfully to show differences in exercise programmes with different loading dosages. Searching for equivalents in the equine sector of tendon injuries finds no equine version of the VISA-OM symptom or functional scoring methods, despite the frequency of these injuries and requirement for assessing rehabilitation techniques. Monitoring of recovery from tendon injury in horses is commonly performed with repeated diagnostic ultrasound and lameness examinations [30]. In terms of monitoring the severity of back pain there is scope to evaluate specific individual physical impairments such as posture, range of motion, response to palpation and as well as global factors such as quality of gait or functional status. Examples of condition specific measures used in human practice, known as patient-reported outcome measures, are the Roland-Morris Questionnaire or the Oswestry Low Back Pain Disability Index which consists of 10 items: pain intensity, personal care, lifting, walking, sitting, standing, sleeping, sex life, social life and travelling [26]. Gathering data such as these in equine practice requires a person to report as a proxy for the horse. Whilst therefore not fulfilling the full definition of a patient reported outcome measure, one specifically designed and validated outcome measure for equine musculoskeletal conditions, with strategies in place to limit observer bias, would allow the evaluation of rehabilitation methods.

In comparison to horses, it is possible to assess outcomes in dogs undergoing rehabilitation using validated scoring systems. The Canine Brief Pain Inventory is an owner-completed questionnaire containing questions on severity of pain and how pain interferes with the dog’s activities. This measure can evaluate changes on pain scores in dogs with osteoarthritis treated with medication or a placebo [31]. In the Finnish canine neurological function testing battery, which assesses functional activities, 11 tasks are scored from 0 to 4, with a maximum sum-score of 44 reflecting dogs with normal motor function [32]. This canine score is not intended for use to assess function in dogs with orthopaedic pathologies however these examples from canine outcome measures show that there is a range of methods that can be used for scoring, and therefore it is apparent that it would be valuable for a potential scoring system for equine rehabilitation to be developed.

The aim of this narrative review is to discuss the options and tools available to use as outcome measures in relation to the treatment and rehabilitation of back pain in the horse.

## 2. Conformation and standing posture

Subjective assessment of posture is discussed as part of a physiotherapy assessment [33] especially in relation to back pain where an extended, lordotic posture has been noted in horses with back pain and impingement dorsal spinous processes [4,12]. Increased extension closes the space between the spinous processes which also this occurs when the head and neck are held high [34] and manually facilitated flexion significantly increased the interspinous spaces in the thoracic spine [9]. Vertebral problems have also been associated with changes in neck posture [35]. This perceived increase in extension could be due to osseous pathology or due to increased tension (spasm) in the epaxial muscle *longissimus dorsi* [36] which does further suggest that the adaption to the position of the equine spine due to pain is reflected in a change in posture.

Posture relates to the arrangement of the body parts and can alter; however equine assessment also includes evaluation of confirmation [37]. Objective measurement of skeletal conformation can be obtained from standing horses by measurement of segment lengths and joint angles. Historically it has been perceived that horses with shorter backs have a higher incidence of osseous disorder such as impinging dorsal spinous processes, with long backed horses more prone to soft tissue injuries [3]. This is supported by Johnston et al who reported that show jumpers had shorter lumbar spines compared with dressage horses. Yet it cannot be established if the difference in incidence rates of over-riding dorsal spinous processes between jumping and dressage horses is a result of the difference in lumbar conformation or sporting discipline. There is now further ambiguity regarding back length and over-riding dorsal spinous processes with more recent studies suggesting that longer backs are at risk of back pain and osseous pathology. Takeyama and Sasaki [39] found that horses with longer back length, and a greater ratio of caudal to cranial thoracic length had greater muscle hardness which was directly correlated with osseous changes. Pathology could be a result of the higher extension forces that longer backs are exposed to [40], increasing risk of impingement, articular process joint osteoarthritis and increasing the demand on the epaxial and hypaxial muscles to resist gravitational extension forces.

Despite the reference to posture changes in horses with back pain the ability to measure the complex three-dimensional shape change that occurs in the thoracolumbar region of the horse remains challenging. Two-dimensional sagittal plane measures have been shown to have excellent short-term intra-rater reliability in groups of clinically normal horses using total thoracolumbar angle but have not been evaluated for reliability or validity longitudinally [41]. Subsequently more complex geometric morphometrics have shown differences in postures of horses kept under natural conditions to those in riding schools [42] and immediate posture changes following lunging with selected lunging aids [43]. It would be valuable to use either or both measures to track changes in posture longitudinally with respect to rehabilitation of back pain.

Short term change in posture has been documented after completion of dynamic mobilisation exercises in which the horse moved through spinal positions, in standing, by following a food bait. Shakeshaft and Tabor [44] used a flexible curve ruler, adapted with attachment to a spirit level to ensure reliability of measurements, to show that the thoracic region of the horse was less lordotic immediately and one hour after the exercises. The spinal contours can be objectively measured with a tool or via analysis of photographs, however the ensuring that the standing position the horse is consistent between repeated measurements is critical [41]. A square stance is commonly described as when the head and neck are in a neutral position and the metatarsus is perpendicular to the ground. Positioning the horses' limbs via stepping forward and back, or handler placement, and using positive and negative reinforcement cues via equipment worn by the horse has been used in studies assessing posture and conformation [41, 45-46] however it is important to note that a self-selected non square stance may be a method of achieving stability and should be noted as part of the clinical evaluation [47].

3. <u>Muscle dimensions</u>

A result of back pain reported in the literature is atrophy of the epaxial muscles [48] and therefore measurement of changes in dimension during ongoing pathology or recovery during rehabilitation is useful. In the laboratory or veterinary scenario, the gold standard measure of muscle size in the standing horse the quantification of cross-sectional area by ultrasound imaging, which has excellent intra-rater reliability when tested using blinded observers [49,50]. Ultrasound imaging has been used to demonstrate changes in multifidus dimensions following exercise rehabilitation interventions and whole body vibration [50-53]. Equipment, cost and preparation time are prohibitive to the practitioner working in clinical practice, however a simple and inexpensive tool that can be used to record epaxial region shape change is the flexible curve ruler which has been used to track change in back dimensions longitudinally [54], the relationship between lameness and saddle slip [55] and change as a result of a vibration therapy intervention [56]. In addition to the flexible curve ruler thoracic profiles size measures extracted from a three-dimensional light-scanning tool has been tested in a group of endurance horses, showing good-excellent inter-rater reliability [57]. Whilst three-dimensional light-scans use equipment that is less expensive than an ultrasound imaging machine and are non-contact thus not requiring clipping/shaving or a contact medium, they have yet to be used to evaluate shape change as a result of rehabilitation.

Muscle scoring, a subjective and visual grading scale of muscle development, has also been shown to have moderate to very good repeatability when used in combination with palpation and scored with categorical scales. Walker et al [58] assessed 35 dressage horses and the muscle score was related to the kinematics of the same horse when ridden, showing greater thoracic, abdominal, and lumbosacral muscle scores were associated with larger lumbosacral flexion angle during stance and swing, and smaller thoracolumbar flexion angle during swing phase in collected trot. A more recent research study modified the muscle scoring template and developed a muscle atrophy scoring system for horses [59], testing its use in horses with a wider range of ages, breeds and health status. Inter-rater agreement using a scoring scale which ranged from 1 (“no atrophy”, i.e., normal muscle mass) to 4 (“severe atrophy”), with half scores permitted was shown to be good-to-excellent for the neck, back and hind regions. Pallesen et al [60] also developed an equine muscle condition score, which was tested on 25 thoroughbred horses, based on a-priori muscle mass values measured using ultrasonography. In their system horses were given and overall score that best described the whole horse after assessing seven areas including the back. Walker et al [58] and Herbst et al [59] used a composite score for their grading, allowing for more evaluation of regions than Pallesen et al [60] which is potentially more useful for a wider range of breeds and disciplines of the working horse. In the context of muscle scoring for horses with back pain, particular attention is given to the thoracolumbar region's profile, specifically where the region may exhibit a pronouncedly concave profile. This is contrasted with the opposite end of the spectrum, a flat or convex shape which is an indicator of desired muscle development.

A limitation to the use of external shape is that the total profile includes both muscle and adipose tissue. Whilst Herbst et al [59] attempted to correct the score for this and Walker et al [58] suggest completing a body condition score in addition to their muscle evaluation, both these scores and the use of a flexible curve ruler cannot identify if changes in profile size are muscle change, adipose tissue quantity change or a combination of both. Ultrasound imaging does allow measurement of muscle but only when the whole border of the muscle can be visualised on the screen, such as the multifidus muscle. Unfortunately, cross-sectional area change of the multifidus muscle does not correspond to total external profile shape change [61] which limits ability to judge change in muscle size of deep stabilising muscles such as multifidus, via external methods. Singular dimensions of the longissimus dorsi muscle has been measured with ultrasound imaging, with Lindner et al [62] and Abe et al [63] studying thickness which has been taken forward to studies investigating treatment effects of pituitary pars intermedia dysfunction [64] and seasonal growth in young horses [65], but as yet, not for changes as an effect of rehabilitation for back pain.

4. <u>Palpation</u>

To objectively measure the response to manual palpation over the back regions in a horse, as verbal feedback is not obtainable, a tool needs to be used to provide feedback in a form that is recordable. To evaluate the effects of extracorporeal shockwave and capacitive resistive electric transfer therapy treatment on horses with thoracolumbar pain categorical scores have been used by Trager et al [66] and Argüelles et al [67] respectively. Both studies used categories and a four-point scale to record response to palpation over the spinous processes, palpation of the epaxial musculature and to visually grade epaxial muscle atrophy. Each score is listed with guidance to the behavioural response, level of muscle tone or amount of muscle loss but did not address variations in muscle sensitivity within an individual muscle. Muscle tone is undefined, but if assumed to be the amount of tension in the muscle at rest, this would relate to the muscle scored as soft or stiff according to the scales. There are no reports of reliability testing for these scales however both studies used a single examiner to test and record the scores with these scales [66,67].

The inter-rater reliability of palpation assessment using categorical scores have been tested by Varcoe-Cocks *et al* [68] and Merrifield-Jones et al [69] where 6-point scales combining pain response and evaluation of tone, have been shown to have no significant differences for reported on pain between examiners. Therefore, as simple, no-cost methods of documenting graded response to palpation, categorical scores more detailed than presence of pain yes/no are recommended to be used by practitioners. Although inter-rater reliability has been evaluated for a single region in the thoracolumbar epaxial musculature [69], further development of agreed definitions of palpation responses, differences between anatomical locations and tissue quality is needed to avoid the variations in interpretation of palpation seen between practitioners.

The most used mechanical tool is the pressure algometer which quantifies the mechanical nociceptive threshold (MNT) using a tip of a known size, usually 1cm$^2$ and a calibrated scale that measures force [70]. The pressure applied via the tool is stopped when there is a behavioural response from the horse indicating pain/discomfort from the musculoskeletal structure it is applied to. The resultant data, in units such as Newtons per cm$^2$ or kilograms per cm$^2$ can then be tracked across periods of time. Based on the decline in MNTs in horse with experimentally induced back pain there is a validity to using a pressure algometer to measure MNT responses [70,71]. A pressure algometer has been used in several studies to evaluate the response to interventions, such as chiropractic manipulation, elastic therapeutic tape and extracorporeal shockwave as well as documenting values in ranges of horses such as racehorses with sacroiliac pain, warmbloods and

Icelandic horses [66,68,72-75]. Whilst the MNT level is provided on a quantitative scale it is important to note that horses can become sensitized or habituated to the application of the pressure algometer with all the above authors noting changes in repeated measures ranging from increasing MNTs in 20-26% and decreasing in 6-23% of horses, [70,72,74], significantly lower readings in the middle of two of four measures [68], differences in readings at different times of the day [74] and differences following a control treatment application [73]. If using a pressure algometer it is critical that a protocol is established regarding consistency of location tested, time of day the horses is being measured, time of measurement relative to exercise speed of application and the number of repeated measures on the same location that are used to inform the mean MNT.

The pressure algometer, used to measure MNT is considered to be a repeatable measure of pain response, however a similar tool, applied to the soft tissues of the back region has been used to quantify muscle tone. Wakeling et al [76] used a custom-made indenter that used a linear variable displacement transducer to produce a voltage output when placed in the epaxial region due to displacement of the spring. The output, in Newtons per metre, were used to record changes in muscle tone following manipulative therapies. Whilst tone is mentioned in categorical scoring systems for palpation, the objective device used by Wakeling et al [76] does not appear to have been used in any further equine studies of back pain treatment.

## 5. Range of motion

Thoracolumbar range of motion is routinely assessed as part of evaluation of spinal function, and this can be achieved in the standing horse by stimulating reflex muscular contractions to induce movements as a response to the pressure [77,78]. Pressure on the ventral midline, known as the pectoral, sternal or abdominal reflex is said to not only demonstration range of motion of the thoracic region but the ability of the horse to activate abdominal and trunk musculature, and with dorsal pressure the pelvic rounding or croup reflex can assess more caudal regions of the spine [78]. Regular use of these reflex mobilisations are suggested to prevent loss of spinal motion. Although there are no published reports of their longitudinal efficacy, they do induce a kinematic or postural change, as well as activate the abdominal muscles, shown by Coll et al [79]. Measurement of muscular activity requires specialist equipment and analysis, therefore is unlikely to be used in clinical practice, however objectively measuring the change in available thoracolumbar movement as a result of treatment or a rehabilitation programme range, via a method convenient to use by a sole practitioner would be of value.

Interest in the available range of motion of the equine spine has been long standing with early research measuring the motion of the thoracolumbar region during induced back movements [80]. The aims of Licka and Peham's study [80] were, to provide objectivity to the clinical assessment of evaluating the ability and willingness to perform these spinal movements [3]. The mean range of dorsoventral and lateroflexion movement, measured with three-dimensional kinematic analysis was presented as percentage of the horse's height at the withers. Whilst objective, and documented without bias, the value of this measure is limited due to low external validity with only ten horses albeit of mixed breeding as well as the challenge to observe small difference in relative percentages based on the height of the horse. Measurement of lumbosacral range of motion in the standing horse during electrical stimulation and induced back movements was measured in a more recent study evaluating the effects of the electrical stimulation [81]. Using three-dimensional kinematic analysis the flexion-extension range of segments of the thoracolumbosacral region can be documented however in a clinical setting these methods are not practical.

Categorical scoring of the observation of induced back movements has been used to evaluate the outcome of therapeutic interventions. When testing the effects of a pulsed electromagnetic rug a self-created scale was used that noted a physiological reaction being normal as a zero and positive or negative for increased or decreased reactions (mild = +/- 1; moderate = +/- 2 and severe = +/- 3) [76]. Although there was no significant difference to this or the pressure algometry used, the authors do discuss that this method of testing remains subjective and requires an experience examiner using a standardised protocol. The effects of chiropractic care and low-level laser therapy were also evaluated using a battery of tests including palpation and range of motion tests, using categorical scoring [83]. Responses to sternal elevation and pelvic flexion reflexes were scores in a scale from 0 (Pronounced pain response, steps away/avoid applied pressure) to a maximum of 4 (≥ 3cm wither elevation or pelvic flexion and ability to hold the position indefinitely). The authors do not describe how the amplitude of movement was determined, or why the threshold of ≥ 3cm wither elevation or pelvic flexion was selected. Therefore, it would be interesting to objectively compare vertical displacement in horses of different breeds and confirmations, and those with and without back pain, to determine if the average displacement range is appropriate to use in future range of motion studies. Hypomobility leading to a reduced displacement is often reported however hypermobility may also be observed in acutely sensitive and painful horses, or horse with atrophy and potentially influence neuromotor control. Therefore, references ranges that take into account the quantity of motion, palpation and muscle score are needed to established normative values, as well and individual variation. However, as a scale for recording responses to tests of range of motion, to be used without complex video motion analysis, these scales are an advantage over a minimal binary can expected full range be achieved or not.

## 6. Objective gait analysis

Reliable assessment of gait by visual methods alone is known to present challenges [84] but with gait being affected by back pain [12] and back movement affected by lameness [13,14], it is important that some form of objective evaluation of the horse during locomotion be carried out during rehabilitation. If measurement technology such as inertial motion sensors or markerless artificial intelligence systems are available, these are recommended to be used as they can classify asymmetry, limit observer bias and remove the limitations of the human eye to detect mild lameness [85]. In the absence of available technology an ordinal grading scale can and is frequently used but there must be acknowledgement of reduced inter-rater reliability, especially when used to assess mild lameness [86], which may be the level of lameness present in horses undergoing rehabilitation.

During initial stage of rehabilitation, the horse may be on box rest, or restricted to walk [48] which limits evaluation of lameness usually conducted at trot due to the clear association between lameness and alterations for a range of gait parameters (see 84 for a review). However, during in-hand walk several markers can be used both objectively and visually. Vertical displacement of the head movement is also altered at walk after induction of forelimb lameness [87]. Therefore, head movement during forelimb stepping in walk may be a feature to look out for if lameness and back pain co-exist, which is common a feature of the symbiotic relationship explored by Landman et al [8]. Due to lowered muscle activity, thoracolumbar motion is larger at walk than at trot [88] therefore observation of trunk movement could be graded, albeit subjectively. It is possible that future technological developments will enable spinal motion assessment via marker less single camera systems, similar to the systems that are comparable to three-dimensional motion capture for lameness evaluation [89]. The potential for computer vision to detect changes in posture is promising as systems are being developed to monitor animal movement and position, which although as valuable for welfare assessment [90] the advances in technology could become accurate enough to acquire equine kinematic data. In addition to immediate data acquisition, the reliability of the measures gained between assessments is critical to being able to evaluate changes longitudinally. Inertial motion sensors have demonstrated moderate intraclass correlation coefficients for weekly repeat gait assessments when measuring asymmetry in thoroughbreds [91] However, with the potential for more extensive use of this technology over longer periods, objective gait analysis may prove valuable in tracking rehabilitation progress

## 7. Thermography

Thermography is a tool to detect of infrared radiation, which can be directly correlated to blood flow. Superficial body temperature increases result from alterations in local blood flow which can be due to an active inflammatory processes and injuries of underlying tissues [92]. In a rehabilitation context thermography could record local increase in temperature due to an inflammatory process but also the presence of different pain degrees, evaluating the efficacy of the treatment [93]. von Schweinitz [94] recommends not only looking for thermographic hot spots which indicate regions where inflammation may be present, but also areas within chronic back pain cases involving cold regions at the affected sites. In some muscle injuries, swelling and oedema in the affected area may be severe enough to inhibit blood flow through the muscle, highlighting the importance of comparison between right and left sides [92].

Despite reports of its value, for example in supporting diagnosis of thoracolumbar lesions in Quarter Horses [95] and nonracing performance horses [94], limited studies into thermography as a monitoring tool in horses undergoing rehabilitation have been published [93]. Challenges acquisition of reliable thermographic images exist such as the influence of hair, its uniformity and its length, airflow/drafts and the presence of sunlight creating erroneous heating of the skin [92,93,96]. To enhance the value of thermography as a measure of rehabilitation progress, a rigorous protocol should be adopted [96]. With more research to establish the reliability of thermography across all equine applications there is potential for use as a screening or complementary test to guide further diagnostic examinations and documenting evidence supporting the effects of various physical therapies and rehabilitation techniques [94]

## 8. Functional evaluation

A more functional but potentially difficult area to assess validity of, is the capacity of the horse undergoing rehabilitation to complete a task. During walking in early stages of rehabilitation or when progressed to trotting, ground and raised poles are often suggested as part of a rehabilitation programme [97]. When measured with electromyography, walking over poles have been shown to increase the activity of *longissimus dorsi* and *rectus abdominus*, and trotting to increase *rectus abdominus* activity [98]. The effect of increasing the hypaxial muscle activity, to induce flexion of the thoracolumbar spine, supports the use of poles as part of rehabilitation for back pain. The limb flexion range of motion during stepping over ground and raised poles, increases at the elbow, carpus, metacarpus, stifle, hock and metatarsus [99,100], suggesting that range limb flexion could be a proxy measure for core stabilisation, which is a desired outcome of rehabilitation [53]. Tracking ability to change the amount of flexion to adapt to the obstacle, in this case a pole on the ground or raised could be a used to monitor progress through rehabilitation.

There is very little reported regarding fatigue and the effect on movement in horses. In horses progressing from durations of no work to fitness, or in horses already at higher levels of activity, it is plausible that fatigue would influence quality of movement, neuromuscular control and potentially pain levels. Before and after a 19-minute duration of water treadmill exercise at walk, at five water depths, limb kinematics and poll/wither and pelvis displacement in six horses were analysed [88]. Whilst stride direction, fore/hindlimb protraction and retraction, and craniocaudal, mediolateral and dorsoventral poll/wither and pelvis displacement were not altered there was a significantly greater mediolateral oscillation of tarsus during the stance phase of the stride in all horses. Tarsal oscillation may be a sign of reduced strength in the hindlimb stabilising musculature (Quadriceps and Biceps Femoris) and potentially could predispose the horse to injury [101]. In clinical practice assessment of tarsus oscillation could be achieved in real-time and graded as per Tranquille et al [102], who used an ordinal scale with three categories of no oscillation, mild and severe to track change. Using a scoring system to monitor features of gait such as tarsal oscillation or limb flexion during exercise with poles and their change during a rehabilitation programme, is a step towards objectivity and a potential method of reducing the risk of expectation bias. In respect to function of the spinal regions a scoring system for, or an in the field method of objectively quantifying, thoracolumbosacral mobility during gait would be an extremely valuable addition to the rehabilitation practitioner's measurement toolkit.

A grading scale has been developed for assessment of function during movement and it could be used for tracking achievement of any task, similar to scales previously validated for human and canine function. The equine scale, designed through consensus with expert physiotherapists contains five levels and descriptors starting with optimal, and progressing through good, mild movement dysfunction, moderate movement dysfunction and severe movement dysfunction [103]. Whilst this system is subject to further reliability and validity trials, in the absence of computer aided analysis of gait or complex tasks like negotiating an obstacle, this grading scale is legitimate and logical step towards more objective documentation. To improve goal orientated approaches to rehabilitation a recommendation is to use a modified patient specific functional scale, either with an ordinal 0-10 score or the 0-5 scale reported above, individualised to the horse presenting with back pain, to monitor effectiveness of interventions [104].

## 9. Owner reported outcome measures

Within the literature relating to surgery for impinging dorsal spinous processes, there are owner reports gauging long term outcomes. Where standardised veterinary assessments of the horses were not performed in the months following the surgery, owners were contacted by telephone [10,15,48,105-109]. For obvious reasons neither the owners nor those conducting the telephone interviews were blinded to the treatments and the range of follow-up timeframes were from six months to six years, which challenges the validity of the results. In human clinical practice patient-reported outcomes are used as a marker of effectiveness for many interventions, however an acknowledged limitation of their use of recall bias. After a relatively short period of two weeks following spinal injection Butt et al [110] patients showed significantly altered recollection of pain levels when patients were asked about their pain levels pre- and four-hours following the treatment. No studies appear to be published on recall bias, or validity of non-blinded reviews of outcome following surgery for impinging dorsal spinous processes.

## 10. Pain scales

Evaluation of pain is a critical element of musculoskeletal assessment and there are a variety of reliably tools that are available to record alteration in facial expressions [111,112] and ridden behaviour [113] however these are not specific to back pain, or indeed musculoskeletal pain. Scales for orthopaedic pain and subsequent change of behaviour have been designed, such as the equine brief pain inventory for osteoarthritic horses [114] and the musculoskeletal pain scale [115] which score discomfort based on demeanour, pain face, head/neck posture. limb posture, weight shifting and bearing and lameness. Arguably to date there are no behavioural or functional outcome measures of equine back pain that have been validated and published.

## 11. Recommendations

A gold standard outcome measure relevant to the context of this article will have been tested for validity in horse with back pain, such as pressure algometry, flexible curve ruler and three-dimensional kinematics (spinal and limb). If a valid measure is not available the next level of quality is whether it is reliable in the context of horses with back pain, and then in clinically normal horses, for example posture measurements from photographs.

If no outcome measure exists, it is sensible to create your own categorical scale which can be as simple as mild, moderate and severe, or more complex with greater numbers of categories. Whilst subjective and therefore still open to observer and expectation bias, by documenting scores beyond a binary improved or not, there is more scope for being evaluative and reducing relying on memory and recall bias.

To assist choosing the most optimal outcome measure for the horses with back pain undergoing rehabilitation, the following questions can be used:

- Are you evaluating a single impairment factor or whole-horse dysfunction?
- Has the outcome measure been tested for validity in the clinical population you wish to use it in?
- Has the outcome measure been tested for repeatability either within or between those taken the measures (intra- and inter-rater reliability)?
- Does this outcome measure need equipment or facilities to be used, and do you have access to those required?
- Will the owner or the practitioner be collecting the measurement?
- Is the horse restricted in their activity levels?

## 12. Conclusion

Both objective measurement of a horse in standing and during motion are important to gain a true picture of the horse, and how the back is functioning, in horses undergoing treatment and rehabilitation. Unfortunately, there are drawbacks to over-reliance on the commonly used subjective visual examination, in the form of bias, leading to false positive or negative reporting of results. Complex laboratory-based analysis systems are available to be gold-standard truly objective systems, however realism for clinical practitioners working in the field limits their use. There is a requirement for new outcome measures that are not time or financially consuming. Any outcome measure is better than no outcome measure, and choosing those that reduces subjectivity can assist with clinical decision making for the benefit of the horse.

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