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Review

Systematic pain assessment in horses

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ABSTRACT

Accurate recognition and quantification of pain in horses is imperative for adequate pain management. The past decade has seen a much needed surge in formal development of systematic pain assessment tools for the objective monitoring of pain in equine patients. This narrative review describes parameters that can be used to detect pain in horses, provides an overview of the various pain scales developed (visual analogue scales, simple descriptive scales, numerical rating scales, time budget analysis, composite pain scales and grimace scales), and highlights their strengths and weaknesses for potential clinical implementation. The available literature on the use of each pain assessment tool in specific equine pain states (laminitis, lameness, acute synovitis, post-castration, acute colic and post-abdominal surgery) is discussed, including any problems with sensitivity, reliability or scale validation as well as translation of results to other clinical pain states. The review considers future development and further refinement of currently available equine pain scoring systems.

Introduction

In veterinary practice, adequate diagnosis and treatment of painful conditions is dependent on accurate recognition of pain experienced by non-verbal animals. Pain is defined by the International Association for the Study of Pain (IASP) as an '*unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*' (Merskey and Bogduk, 1994).[1] As pain is a subjective experience that cannot be verbally communicated by animals it follows that no 'gold standard' method is available its measurement in veterinary patients. Horses pose a particular challenge, as they are a species that has evolved so as not to express pain too openly, presumably in an attempt to avoid predation (Taylor et al., 2002a); also, breed influences and inter-individual variation in pain expression may be considerable (Wagner, 2010). Objective and accurate parameters for the presence and severity of pain in horses are needed for ethical and animal welfare reasons (Zimmermann, 1983).

Clinical studies have tended to focus on differences in physiological, endocrine (hormonal/mediator concentrations) and/or behavioural parameters over time and with analgesic treatment in horses with a range of painful conditions, including laminitis, synovitis and colic. These studies have led to the realisation that one pain assessment tool or system may not perform equally well for different types of pain (e.g. visceral vs. somatic pain, acute vs. chronic pain, nociceptive vs. inflammatory vs. neuropathic pain). Experimental studies on models of induced pain have attempted to validate various (neuro)physiological, endocrine and behavioural parameters hypothesised to reflect the presence and/or severity of pain and hypersensitisation in horses, for example by varying the intensity of the stimulus as in thermal or mechanical nociceptive threshold testing (Spadavecchia et al., 2003; Haussler and Erb, 2006). Although such studies may carry ethical and animal welfare concerns, when used judiciously and with sound methodology they can yield invaluable insights in equine nociceptive and pain responses (Ashley et al., 2005).

This review aims to provide an up-to-date descriptive overview of methods for the systematic assessment of pain in horses, highlighting their strengths and weaknesses, and giving directions for future development and potential use in clinical practice.

Searches

PubMed and Google were searched using the search terms 'horse' or 'equine' in combination with 'pain', 'nociception', 'score', 'scale', 'VAS', 'NRS', 'SDS', 'composite pain scale', 'facial expression' or 'grimace'. Articles were screened and selected based on relevance to topic (key focus on recognition of pain or nociception in horses), and their reference lists were scrutinised for articles that may have been overlooked. Additional key words were used to extend this search for the following specific equine pain states: 'laminitis', 'synovitis', 'castration', 'abdominal', 'colic', and 'celiotomy'.

In total, 57 articles were deemed of primary relevance to pain recognition in horses and were included in the review. Given the qualitative nature of many of the studies and the limited number of studies for each method of pain assessment, no meta-analysis

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[1] See: http://www.iasp-pain.org/Taxonomy (accessed 24 December 2014).

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or statistical analysis was performed, and this article thus constitutes a descriptive rather than a systematic review (see also Appendix: Supplementary Table S1).

Approaches to the study of pain: Putative pain-related parameters

Physiological parameters

Parameters such as heart rate and respiratory rate may be affected by pain and are easily measured and quantified; as a result, heart rate is often quoted by equine veterinarians as an important indicator of pain and the need for analgesia (Price et al., 2003; Dujardin and van Loon, 2011). However, these parameters on their own are non-specific for the presence and severity of pain, since they may be influenced by other factors, including ambient temperature, dehydration, excitement and cardiovascular and/or respiratory disease. Studies have often failed to establish a direct relation between heart rate and presence or severity of pain (Raekallio et al., 1997; Dzikiti et al., 2003). Therefore, these parameters are best incorporated into a composite pain assessment system that also includes behavioural components, such as that of Bussières et al. (2008).

Endocrine measures: Hormone and mediator concentrations

Levels of circulating endogenous cortisol, β-endorphins and catecholamines have been evaluated as indirect indicators of pain in horses (McCarthy et al., 1993; Pritchett et al., 2003; Rietmann et al., 2004; Virgin et al., 2010). However, as previously noted, the relation between physiological stress, behavioural distress and pain is complex (Ashley et al., 2005; Wagner, 2010); hence, endocrine measures may reflect stress responses that may not be pain-induced (Virgin et al., 2010; Erber et al., 2012), and the magnitude of change may not be related to the extent or severity of pain (McCarthy et al., 1993). Although there may be a rationale for inclusion of endocrine measures in experimental studies of pain-induced stress (Virgin et al., 2010) and clinical studies of the stress response (Erber et al., 2012), these parameters cannot be relied upon as indicators of pain in horses.

Pro-inflammatory mediators, such as prostaglandin (PG) E_2, substance P and bradykinin, lower the threshold of C-fibre activation and may directly activate such fibres. Measurement of these mediators in inflamed or infected tissues or body fluids is often included in orthopaedic studies when quantifying inflammation (Frisbie et al., 2008; de Grauw et al., 2009a, 2009b; Lindegaard et al., 2010). In one study, synovial fluid substance P level was related to the response to intra-articular (IA) anaesthesia (de Grauw et al., 2006). Reduction of the concentration of synovial PGE_2 with non-steroidal anti-inflammatory drugs (NSAIDs) or IA morphine treatment is consistently associated with attenuation of lameness (de Grauw et al., 2009a, 2014; Frisbie et al., 2009; van Loon et al., 2010). However, it is unlikely that absolute concentrations of inflammatory mediators in local tissue fluids can be used to quantify levels of pain (de Grauw et al., 2006).

Behavioural aspects of pain

Unpleasant sensory and emotional experiences that constitute pain give rise to subtle or overt changes in behaviour that may offer the strongest indication of the presence, localisation and severity of the pain. Several studies have established non-specific indicators of pain in horses, while others have attempted to identify behavioural expressions related to specific types (acute or chronic) or sites (abdominal, distal limb) of pain (Ashley et al., 2005).

Aspects of behaviour that may be altered by pain include elements of demeanour, posture and gait, as well as interactive behaviour. However, a horse's behaviour is influenced by factors other than pain, including breed, temperament, sex, age and (familiarity with) environment (Wagner, 2010; Minghella and Auckburally, 2014). The amount of time needed to carefully observe and assess a horse's behaviour may be a limiting factor in clinical practice (Ashley et al., 2005).

In clinical studies where patients with painful conditions are assessed, two important limitations are encountered. Firstly, no baseline evaluation of the horse's behaviour before the pain occurred is available. Secondly, the horse is seen in distress in a novel environment and this is difficult to correct for. Clinical studies tend to use pre- and post-operative settings or pre- and post-analgesia time points, since these allow each horse to be used as its own control, thus correcting for baseline differences in temperament or demeanour.

Pain assessment systems

Systematic assessment of pain using defined and validated pain scoring systems or scales will help to improve recognition and treatment of painful conditions in horses. In addition to raising awareness of such pain states, they may enhance agreement between different observers or caregivers on the amount of pain a horse is experiencing, thus providing a reliable record of pain severity over time (Dutton et al., 2009; Wagner, 2010).

In order for a pain scoring system to reliably work in practice, it should be easy to use, with relevant well-defined parameters that can be assessed repeatedly and quickly by different observers with consistent results (Wagner, 2010). The pain scale should be sensitive enough to detect mild, moderate or severe pain, ideally have a linear relation with pain severity, and be validated and specific for the type of pain being assessed (Ashley et al., 2005). Methods used for validation of pain scoring tools have been described elsewhere (Brondani et al., 2013; Taffarel et al., 2015) and include assessment of internal consistency, construct validity, responsiveness, and reliability of the scale in clinical cohorts of patients and controls. It should be noted that formal scale construction and thorough clinical validation has not been pursued for most equine pain scales.

Among the tools that have been investigated and employed for objective assessment of pain in horses are the visual analogue scale (VAS), simple descriptive scale (SDS), numerical rating scale (NRS), time budget analysis, composite pain scales (CPS), and scales based on facial expressions of pain (Wagner, 2010).

Visual analogue scale

The VAS consists of a horizontal 10 cm line, representing pain intensity that increases from none at the beginning (left) of the line to the worst imaginable pain at the right. An observer can put a mark anywhere along this line that corresponds to the perceived amount of pain an animal is experiencing. The pain score is then read off as the number of millimetres from the zero end of the scale. A VAS score is a continuous variable and is easy to use. However, the extent to which VAS scores truly reflect a pain continuum rather than discrete classes is questioned by studies in humans who may self-report that they are in the same amount of pain as a few minutes before but provide a VAS score differing by up to 20 mm from their previous entry (DeLoach et al., 1998; Bailey et al., 2012).

Observational VAS scores used in human paediatrics have demonstrated inter-rater reliability ranging from 0.36 to 0.91, meaning only fair to excellent, depending on the study (van Dijk et al., 2002). In equine practice, VAS scores will be influenced by the amount of time taken to observe a horse, and inter-observer agreement tends to be suboptimal, particularly towards the middle and lower end of the pain scale (Lindegaard et al., 2010; Sutton et al., 2013a; J.P.A.M. van Loon and M. van Dierendonck, unpublished data).

Numerical rating scale

The NRS consists of a horizontal line with pre-set number tags from zero to 10 at equal distances along the line. Again, zero designates no pain and 10 the worst imaginable pain. Observers are asked to circle the number closest to the perceived amount of pain the animal is experiencing. An NRS score is therefore a discontinuous (i.e. discrete) ordinal variable. It tends to be more repeatable than the VAS due to its discontinuous nature; inter-observer reliability of a six-point NRS in acute colic horses was deemed good, based on an observed intra-class correlation coefficient of 0.67 (Sutton et al., 2013b). The NRS is presumed to be less sensitive for identifying small changes in pain than the VAS, since only pre-set whole number (integer) entries are allowed (Ashley et al., 2005). Although based on canine studies, Holton et al. (1998) argued that VAS scores create a false sense of sensitivity.

Simple descriptive scale

An SDS consists of pre-defined classes or degrees of pain to which an index number is assigned to allow the data to be handled statistically, e.g. 0, none; 1, mild pain; 2, moderate pain; 3, severe pain. While these scales are ordinal, there may not be equal differences between each consecutive class of the scale, i.e. the difference in the amount of pain between scores of 0 and 1 may not be the same as the difference in the amount of pain between scores 2 and 3.

While simple descriptive scales may be expected to perform better than VAS or NRS in the hands of less experienced observers (since pre-defined classes are provided), this is not always the case (Viñuela-Fernandez et al., 2011). Examples of the use of SDS in clinical practice include lameness grading systems, such as the American Association of Equine Practitioners (AAEP) lameness score (Kester, 1991) or the Obel score for laminitis (Obel, 1948).

Time budget/activity budget analysis

Since animal pain leads to alterations in behaviour, normal behavioural or activity patterns will be affected by the presence of pain. To detect such alterations, horses need to be monitored closely for a long period of time. One way to analyse behavioural patterns and changes is to observe horses using continuous videotaping and later to evaluate the films to determine ‘activity budgets’, which constitute the times animals spend on each pre-specified behaviour (e.g. eating, standing with head above withers height, ears forward; Price et al., 2003). Another approach is to obtain sufficiently long clips of film at separate time points, again noting the time a horse spends on each pre-defined observable behaviour (e.g. eating, drinking, lying down, pawing). This time is then expressed as a percentage of the total duration of the video segment to calculate a ‘time budget’ for each behaviour (Pritchett et al., 2003). While the latter method reduces the time needed for monitoring and video analysis, continuous monitoring may have greater sensitivity for picking up pain-related behaviours than intermittent observations (Price et al., 2003).

Although these approaches appear relatively sensitive for detection of even mild pain and can help identify subtle effects of treatment, the investment of time and equipment restrict use to a research setting. Also, activity and time budgets, as pain indicators, do not become available in real time, so clinically they cannot be used to guide intervention.

Composite pain scales

Since pain is a complex, subjective multi-dimensional phenomenon evoking emotional, behavioural and physiological responses, concomitant evaluation of several putative pain-related parameters would be expected to better identify and quantify pain (Dobromylskyj et al., 2000). Clinically, this approach takes the form of construction of composite pain scales (CPS), where multiple variables (behavioural, physiological or both) are scored individually using well-defined classes by means of SDS, which are then combined to provide an overall CPS score. Several experimental and clinical studies, as well as case reports, in horses have made use of composite assessment tools for pain evaluation (Pritchett et al., 2003; Sellon et al., 2004; Bussières et al., 2008; Dutton et al., 2009; Sanz et al., 2009; Lindegaard et al., 2010; van Loon et al., 2010, 2014; Minghella and Auckburally, 2014). Although these CPS systems were not all rigorously devised or validated for the pain state to which they were applied, they have proved their merit in pain recognition and grading, as well as in providing a record of efficacy of analgesic or surgical interventions.

Formal clinimetric development of multi-variable clinical measures such as pain scales should ideally follow three stages: (1) variable (or ‘item’) generation; (2) item selection, and (3) weighting (Sutton et al., 2013a). The variables to be included in any composite pain scale should be specific for the type of pain assessed and easy to recognise or measure with high inter-observer agreement. Although CPS construction in equine studies has generally not followed robust clinimetric methodology, on the whole it appears that the prerequisite of high inter-observer reliability of pain scores is better met by CPS than by NRS or VAS (Lindegaard et al., 2010; van Loon et al., 2014).

Practical drawbacks of CPS methods include the need for experienced and/or trained observers and the time needed for repeated evaluation, although the latter may be reduced by step-wise elimination of those variables that have proven least sensitive and specific for the pain state to which the CPS is applied (van Loon et al., 2014). The observed maximum amplitude of CPS scores in clinical cases tends to be limited (in one study the maximum theoretical score of 39 was never approached, with most strangulating colic cases reaching a maximum score of 15; van Loon et al., 2014), conveying limited utility in identifying and discriminating mild pain states. Defining meaningful cut-off values above which rescue analgesia should be instituted likewise remains a challenge.

Facial expression pain/horse grimace scales

In recent years, pain scales based on subtle alterations in facial expression have been developed for humans and other species (Langford et al., 2010; Sotocinal et al., 2011; Ahola Kohut et al., 2012). Development of such ‘facial expression pain scales’ or ‘grimace scales’ has in part been driven by the need for more sensitive tools to detect mild rather than only overt pain (Langford et al., 2010).

The Horse Grimace Scale (HGS) was recently described by Dalla Costa et al. (2014) for post-castration pain, while Gleerup et al. (2015) developed an equine facial expression pain scale using two experimental nociceptive stimuli, validating several facial features consistently associated with severity of pain. These pain scales show promise as they combine several advantages of other pain assessment tools (ease of use, little investment of time or training, and high reliability within and between observers).

Application of systematic pain assessment tools to specific equine pain states

Laminitis

Acute laminitis is considered to be one of the most painful conditions a horse can experience (Wagner, 2010; Dujardin and van Loon, 2011). The laminitis pain scale developed by Nils Obel is an SDS that classifies the severity of lameness due to laminitis by grade from I to IV (Obel, 1948; Wagner, 2010); the scale incorporates an interactive behavioural component (weight shifting, resistance to having a limb lifted) and a disability component (lameness at walk and/or trot). The Obel scale has been used widely in equine practice in its original or modified form to score pain due to laminitis and the efficacy of analgesic intervention (Rietmann et al., 2004; Dutton et al., 2009; Viñuela-Fernandez et al., 2011). Rietmann et al. (2004) added a hoof tester score to the Obel scale to derive the orthopaedic laminitis pain index (OLPI); endocrine parameters (serum cortisol concentrations) did not improve after analgesic treatment, while heart rate variability correlated with pain and response to analgesics.

In a case report, Dutton et al. (2009) used the grade I–IV Obel scale (designated a 'dynamic score') to derive a modified composite pain score (MCPS) by addition of a 10 point numerical rating scale, incorporating behavioural and physiological components, as a 'static score'; combined dynamic and static scores yielded the total laminitis pain score, with a maximum possible score of 14. Viñuela-Fernandez et al. (2011) evaluated the reliability of three subjective scoring systems for laminitis: VAS and two SDS scales, the modified Obel score adapted from Owens et al. (1995) and the 'clinical grading system' (CGS) developed by Taylor et al. (2002b). The overall reliability of all three scoring systems was high, with intra-observer reliability consistently higher than inter-observer reliability, indicating a preference for repeated observations to be made by the same observer using any of the methods (Viñuela-Fernandez et al., 2011). However, the good reliability of VAS scoring in this study is in contrast with results of other studies (Lindegaard et al., 2010; Sutton et al., 2013a; J.P.A.M. van Loon and M. van Dierendonck, unpublished data) but this may be explained, at least in part, because laminitis is very painful and scoring will tend to be towards the higher end of the pain scale. Unexpectedly, both SDS methods proved less reliable in the hands of students than when assessed by qualified veterinarians, whereas it was expected that providing descriptors might help to guide inexperienced observers in assigning consistent grades.

The Obel and CGS grading methods may require experience to correctly interpret the guidelines provided (Viñuela-Fernandez et al., 2011). A VAS was used by Guedes et al. (2013) to monitor progression and response to therapy in a horse with refractory pain due to laminitis; the reliability of VAS scoring was not formally assessed.

Synovitis

Lameness, when not purely mechanical in origin, is an important and readily recognisable sign of pain in horses, and any form of clinical lameness grading is in essence a pain scoring system. Common lameness grading systems include the AAEP scale from 0 to 5 (Kester, 1991) and a semi-quantitative NRS from 0 to 10 (Wyn-Jones, 1988). However, methods for detection of clinical lameness are more subjective and less reproducible than commonly assumed and desirable (Fuller et al., 2006; Hewetson et al., 2006; Keegan et al., 2010). Objective gait assessment techniques such as kinetic (force plate) and kinematic lameness evaluation are available (Wagner, 2010), but require investments in technology and training (Keegan, 2007). When grading lameness clinically, intra-observer reproducibility tends to be good, while inter-observer agreement tends to be poor, with observers more likely to differ on the degree of subtle lameness than the degree of overt lameness (Fuller et al., 2006; Keegan et al., 2010); this emphasises the need for observations to be made by the same observer when longitudinal studies on lameness interventions are performed.

One important cause of lameness in horses is acute synovitis. Experimental studies using IA injections of lipopolysaccharide (LPS) or amphotericin B to induce acute or chronic synovitis, respectively, have been used to validate pain scoring tools and monitor efficacy of analgesic intervention (Bussières et al., 2008; de Grauw et al., 2009a, 2014; Santos et al., 2009; Lindegaard et al., 2010; van Loon et al., 2010, 2012, 2013). Although there are ethical concerns for models of induced pain, they can be valuable for the study of clinical pain states when well designed and with the goals of refinement and reduction in mind (Robertson, 2006).[2]

Using the amphotericin B model, an orthopaedic CPS was developed and validated by Bussières et al. (2008). This CPS includes several interactive behavioural variables (such as response to palpation of the painful area) as well as observational (e.g. posture) and physiological variables (Table 1). Although here no formal rigorous process was followed in construction of this scale, individual variables were verified for specificity and sensitivity to the presence and severity of pain by comparison with control horses and on the basis of incremental analgesic treatment (Bussières et al., 2008). Of the variables included, response to palpation of the painful area, posture and pawing were among the most sensitive and specific indicators of pain associated with severe synovitis. Interestingly, non-invasive blood pressure measurement closely mirrored CPS scores, although the association was only tested by means of correlation analysis.

Among others, the LPS-induced transient synovitis model has been used to study the analgesic efficacy of oral NSAIDs (de Grauw et al., 2009a, 2014; van Loon et al., 2013), continuous rate opioid infusions (Carregaro et al., 2014), epidural morphine (Freitas et al., 2011; van Loon et al., 2012) and buprenorphine (Freitas et al., 2011), IA morphine (Lindegaard et al., 2010; van Loon et al., 2010) and IA ropivacaine with or without morphine (Santos et al., 2009). Pain assessment tools used in these studies included physiological monitoring with blood pressure measurement (Freitas et al., 2011; Carregaro et al., 2014), the CPS according to Bussières et al. (2008), clinical lameness grading on a custom made scale (Carregaro et al., 2014) or the AAEP scale (de Grauw et al., 2009a), an SDS for reaction to joint palpation (van Loon et al., 2010), VAS scores and a composite measure pain scale (CMPS) (Lindegaard et al., 2010). Lindegaard et al. (2010) modified the NRS of Pritchett et al. (2003) to produce a CMPS that showed good inter-observer agreement but limited sensitivity for detecting mild pain, while there was no more than fair agreement between observers for VAS scoring (Lindegaard et al., 2010; Table 2).

A clinical study of joint pain after arthroscopy used the activity budget analysis approach to demonstrate changes in behaviour (exploring, voluntary locomotion), posture (head height) and facial expression (tenseness of lips) associated with post-operative discomfort in horses that had undergone arthroscopic surgery compared to pain free control horses (Price et al., 2003). Horses were monitored continuously with videotapes for up to 48 h post-recovery.

Castration

Although castration is the most commonly performed surgical procedure in horses and is associated with significant peri- and post-operative pain (Love et al., 2009; Sanz et al., 2009), there has been

[2] The ethics of the use of amphotericin B for induction of synovitis may be debated, since it induces severe synovitis with > 1 month of lameness (Suominen et al., 1999), compared to transient lameness induced by intra-articular injection of LPS (de Grauw et al., 2009a).

Table 1
Multifactorial numerical rating composite pain scale (CPS) according to Bussières et al. (2008).

Physiological data	Criteria	Score/12
Heart rate	Normal compared to initial value (<10% increase)	0
	11–30% increase	1
	31–50% increase	2
	>50% increase	3
Respiratory rate	Normal compared to initial value (increase < 10%)	0
	11–30% increase	1
	31–50% increase	2
	>50% increase	3
Digestive sounds (bowel movement)	Normal motility	0
	Decreased motility	1
	No motility	2
	Hypermotility	3
Rectal temperature	Normal compared to initial value (variation < 0.5 °C)	0
	Variation < 1 °C	1
	Variation up to 1.5 °C	2
	Variation 2 °C or more	3
Response to treatment	Criteria	Score/06
Interactive behaviour	Pays attention to people	0
	Exaggerated response to auditory stimulus	1
	Excessive-to-aggressive response to auditory stimulus	2
	Stupor, prostration, no response to auditory stimulus	3
Response to palpation of the painful area	No reaction to palpation	0
	Mild reaction to palpation	1
	Resistance to palpation	2
	Violent reaction to palpation	3
Behaviour	Criteria	Score/21
Kicking at abdomen	Quietly standing, no kicking	0
	Occasional kicking at abdomen (1–2×/5 min)	1
	Frequent kicking at abdomen (3–4×/5 min)	2
	Excessive kicking at abdomen (>5×/5 min), intermittent attempts to lie down and roll	3
Pawing on the floor (pointing, hanging limbs)	Quietly standing, no pawing	0
	Occasional pawing (1–2×/5 min)	1
	Frequent pawing (3–4×/5 min)	2
	Excessive pawing (>5×/5 min)	3
Posture (weight distribution, comfort)	Stands quietly, normal walk	0
	Occasional weight shift, slight muscle tremors	1
	Non-weight bearing, abnormal weight distribution	2
	Analgesic posture (attempts to urinate, prostration, muscle tremors)	3
Head movement	No evidence of discomfort, head straight ahead for the most part	0
	Intermittent head movements laterally or vertically, occasional looking at flank (1–2×/5 min), lip curling (1–2×/5 min)	1
	Intermittent and rapid movements laterally or vertically, frequent looking at flank (3–4×/5 min), lip curling (3–4×/5 min)	2
	Continuous head movements, excessively looking at flank (>5×/5 min), lip curling (>5×/5 min)	3
Appetite	Eats hay readily	0
	Hesitates to eat hay	1
	Shows little interest in hay, eats very little or takes hay into mouth but does not chew or swallow	2
	Neither shows interest in nor eats hay	3
Total CPS		39

little formal research to quantify post-castration pain in horses. A CPS was used in one study but could not differentiate between post-castration stallions and control horses; this was interpreted as evidence of effective analgesic treatment in castrated horses (van Loon et al., 2010). Young stallions just admitted to a new (hospital) environment exhibited elevated baseline (pre-operative) CPS scores, likely reflecting stress or excitation rather than pain.

A 'dynamic interactive VAS' (DIVAS) was used to assess the analgesic efficacy of buprenorphine (Love et al., 2013) and butorphanol (Love et al., 2009) for post-castration pain in ponies; in each study, the same experienced observer was blinded to treatment assignment. Scores were assigned after observation for 10 min, noting particular pre-determined behaviours, and included an interactive component. The absolute DIVAS scores per time point and the area under the DIVAS time curve (AUC) were taken as a measure of pain intensity for group comparisons. The DIVAS scores as well as a custom SDS were consistently lower in ponies that received buprenorphine compared to control ponies that received a 5% glucose solution (Love et al., 2013), while the DIVAS AUC in butorphanol + detomidine treated vs. detomidine treated ponies was not significantly different (Love et al., 2009).

Another report on post-castration analgesia evaluated physiological variables, plasma cortisol concentrations, and VAS and SDS scores during treatment with butorphanol and/or phenylbutazone (Sanz et al., 2009). An intra-testicular block with lidocaine was performed intra-operatively in all patients. While VAS and SDS scores, as well as plasma cortisol concentrations, increased after castration, there were no significant differences between treatment groups (Sanz et al., 2009); this may have been due to adequate analgesia provided by all regimes, or to relative insensitivity of these pain scales to small changes in perceived pain.

Martin-Flores et al. (2014) used separate scores for behaviour, posture and socialisation from the NRS by Pritchett et al. (2003) as outcome measures for post-operative pain assessment in horses following cryptorchid castration with or without epidural morphine; gross pain behaviour was reduced at 6 h in the group treated with epidural morphine. The authors proposed that reporting each score separately rather than as a composite score increased the sensitivity of detection of pain. Dalla Costa et al. (2014) used surgical castration to develop the HGS, which is a composite pain scale based on six facial parameters ('action units'): stiffly backward ears, tension above the eye area, straining of the mouth, orbital tightening, straining of masticatory muscles, straining of nostrils and flattening of the profile (Table 3). HGS scores in horses that underwent castration correlated well with composite pain scores that were assessed simultaneously; this scale shows promise for reliable detection of even mild to moderate (post-operative) pain in horses.

Acute colic

Acute colic is associated with overt pain expression in horses and the intensity of pain-associated behaviour may guide the decision for surgery. For a comprehensive overview of typical pain-related behaviours in colic and the strength of literature evidence for each, the reader is referred to the review by Ashley et al. (2005). Sutton et al. (2013a,b) developed and validated two behaviour-based pain scales for horses with acute colic, equine acute abdominal pain scales (EAAPS-1 and -2); these multivariable scales are based mainly on observational behavioural components (Tables 4 and 5) and do not include physiological parameters; they are not composite pain scales, since no sub-scores are added to obtain an overall pain score. Increases in the severity of behavioural expression result in incremental increases in pain score. The inter-observer reliability of the EAPPS-1 and -2 scales was excellent (intra-class correlation coefficients of 0.8 and 0.76, respectively; see Appendix: Supplementary Table S1), indicating they can be used reliably as objective pain assessment tools even in the hands of different observers. Predictive validity of the scales for treatment option (none, medical, surgical, euthanasia) and mortality was also significant (Sutton et al., 2013b). Using a modified CPS based on Bussières et al. (2008) as an indicator of

Table 2
Composite measure pain scale (CMPS) according to Lindegaard et al. (2010).

Behaviour category	0	1	2	3	4
Gross pain behaviour*	None		Occasional		Continuous
Weight bearing	Normal weight bearing or walking	Foot intermittent off the ground/resting more than other thoracic limb		Continuously taking foot off the ground and trying to replace it Carpus slightly flexed	No weight bearing; foot totally off the ground or toe just touching the ground
Head position	Above withers or eating	At withers	Below withers		
Location in stall	At door watching environment	Standing in the middle, facing door	Standing in the middle, facing sides	Standing in the middle, facing back or standing in the back	
Response to open door	Moves to door	Looks at door		No response	
Response to approach	Move to observer, ears forward	Looks at observer, ears forward	Moves away from observer	Does not move, ears back	
Overall subjective pain score	No apparent pain	Mild discomfort	Slight pain	Moderate pain	Severe orthopaedic pain

* Gross pain behaviour is defined as tooth-grinding, lip-curl, pawing, sweating.

Table 3
Horse Grimace Scale (HGS) according to Dalla Costa et al. (2014).

Facial action unit	Description	Score
Stiffly backward ears	*The ears are held stiffly and turned backwards. As a result, the space between the ears may appear wider relative to baseline.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Orbital tightening	*The eyelid is partially or completely closed. Any eyelid closure that reduces the eye size by more than half should be coded as 'obviously present' or '2'.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Tension above the eye area	*The contraction of the muscles in the area above the eye causes the increased visibility of the underlying bone surfaces. If temporal crest bone is clearly visible the score should be coded as 'obviously present' or '2'.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Prominent strained chewing muscles	*Straining chewing muscles are clearly visible as an increased tension above the mouth. If chewing muscles are clearly prominent and recognizable the score should be coded as 'obviously present' or '2'.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Mouth strained and pronounced chin	*Strained mouth is clearly visible when upper lip is drawn back and lower lip causes a pronounced 'chin'.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Strained nostrils and flattening of the profile	*Nostrils look strained and slightly dilated, the profile of the nose flattens and the lips elongate.*	
	Not present	0
	Moderately present	1
	Obviously present	2
Total pain score		12

Table 4
Equine acute abdominal pain scale – version 1 (EAAPS-1) according to Sutton et al. (2013a): to grade the severity of pain the horse is showing, pick the most severe behaviour manifested, and the score for that particular behaviour is the pain score.

Mild	Behaviours	Score
↓	Depression	1
↓	Flank watching	2
	Weight shifting	
↓	Restlessness	3
	Kicking abdomen	
	Pawing	
	Stretching	
	Sternal recumbency	
↓	Attempting to lie down	
	Lateral recumbency	4
Severe	Rolling	
	Collapse	5

Table 5
Equine acute abdominal pain scale – version 2 (EAAPS-2) according to Sutton et al. (2013a): To grade the severity of pain the horse is showing, pick the most severe behaviour manifested, and then choose one or the other of the two scores for that particular behaviour based on the descriptions below the table.

Mild	Behaviours	Mild	→	→	→	Severe
	Depression	1				
↓	Flank watching[a]	1	2			
	Weight shifting[a]	1	2			
↓	Pawing[a]		2	3		
	Stretching[a]		2	3		
↓	Kicking abdomen[a]		2	3		
	Restlessness[b]		2	3		
	Sternal recumbency[c]			3	4	
↓	Attempting to lie down				4	
	Lateral recumbency				4	
↓	Rolling					5
Severe	Collapse					5

[a] The lower score applies if the behaviour is seen RARELY or OCCASIONALLY and the higher score if seen FREQUENTLY or if it is being performed VIOLENTLY.
[b] The lower score applies to a horse that circles in a stall, pivots around with the hind end, or moves for no apparent reason, but only occasionally, and the higher score applies to a horse that moves as above, fairly continuously and aimlessly or moves in a jerky or violent matter.
[c] The lower score applies to a horse that is alert, with raised head carriage and the higher score if horse's head is resting on ground or facing the horse's side.

severity of visceral pain in acute colic cases, we found excellent inter-rater reliability for the CPS compared to poor reliability of VAS scoring (J.P.A.M. van Loon and M. van Dierendonck, unpublished data).

Abdominal surgery

Emergency surgery for colic is a common procedure in equine referral practice, and pain associated with coeliotomy, as well as with the underlying (surgically corrected) condition, may be substantial. Multiple studies have attempted to devise scales for reliable quantification of pain after abdominal surgery in horses, since such pain assessment tools would be useful for clinical decisions and to determine prognosis.

Table 6
Numerical rating scale (NRS) of behaviour according to Pritchett et al. (2003).

Behaviour category	1	2	3	4
Gross pain behaviours[a,b]	None		Occasional	Continuous
Head position[b]	Above withers		At withers	Below withers
Ear position[b]	Forward, frequent movement		Slightly back, little movement	
Location in stall[b]	At door watching environment	Standing in middle, facing stall door	Standing in middle, facing sides of stall	Standing in middle, facing back of stall
Spontaneous locomotion[b]	Moves freely	Occasional steps		No movement
Response to open door[c]	Moves to door	Looks at door		No response
Response to approach[c]	Move to observer, ears forward	Looks at observer, ears forward	Moves away from observer	Does not move, ears back
Lifting feet[c]	Freely lift feet when asked	Lift feet after mild encouragement		Extremely unwilling to lift feet
Response to grain[c]	Moves to door and reaches for grain	Looks at door		No response

[a] Gross pain behaviours include pawing, sweating, looking at the flank, flehmen, and lying down/standing up repeatedly.
[b] Scores combined to yield Posture score.
[c] Scores combined to yield Socialization score.

Table 7
Post abdominal surgery pain assessment scale (PASPAS) according to Graubner et al. (2011).

Category	Sub-category	Manifestation	Assigned value/further description
Physiological	Heart rate (beats/min)	<40	0
		40–49	1
		50–59	2
		>60	3
	Respiratory rate (breaths/min)	<20	0
		20–30	2
		>30	4
Behavioural	General subjective assessment	No signs of pain	0
			1
			2
			3
		Signs of severe pain	4
Behavioural	Postural behaviour	Ears held back and/or head below height of the withers	1 Ears not alert on vocal stimuli, horse holds his head level to or below the withers Makes a depressed impression, no reaction to stimuli from environment, appears withdrawn
		Restless	1 Moving not interested in feed
		No movements	1 Standing still
		Arched back, tucked-up belly	1 Groove between abdominal muscles is visible, back is arched
	Interactive behaviour	Interested	0 = Attentive
		Looks at observer	1 = Slight interest in environment
		Moves away	2 = Avoiding contact
		Does not move	3 = Not reacting, appears to be introverted
	Response to food	Strong appetite	0 = Searches for feed, reacts immediately, when offered feed
		Appetite but wearing a muzzle	0 = Tries to get hold of straw through the muzzle
		Little appetite	2 = Accepts offered feed, is not excited about it and does not try to get more
		No appetite at all	4 = Refuses to eat anything
	Colic behaviour	No colic signs shown	0 = Behaves normally
		Paws intermittently	1 = Pawing is interrupted by short intervals
		Paws and lies down	2 = Repeated attempts to lie down, stall is messy
		Looks at the flank, paws frequently	3 = Indicates the location of pain, increasingly getting nervous
		Rolls, wags the tail, kicks against the abdomen	5 = Gets restless and uncontrolled
		Keeps throwing himself down, rolling on the ground	6 = Out of control
	Stimulation of muscles Th17-L1	No reaction	0 = Does not react at all
		Hardened muscles, reaction shown	1 = Palpable area or a strand of hardened muscles and/or lowers its back, tries to avoid palpation
	Reaction to palpation of the incisional area	No reaction	0 = Does not react at all
		Tenses abdomen/arches back/tries to evade to the side	1 = Groove between the abdominal muscles and/or arch of the back is clearly visible, shows flight reaction, ears are drawn back, might attempt to bite or kick
	Total pain index	1–7 low pain 8–14 moderate pain >14 severe pain	Summation of scores

The NRS developed by Pritchett et al. (2003) used physiological and behavioural indicators of postoperative pain in horses to monitor the efficacy of analgesic intervention. Using time budget analysis on 1 h segments of film to quantify behaviour, Pritchett et al. (2003) found that, post-surgery, horses spent more time displaying painful behaviour (although this was for only a short duration of total observation time) and with less time in voluntary locomotion. The NRS devised by Pritchett et al. (2003) assigns a numerical score to each category of behaviour that is weighted based on a description of that behaviour (Table 6); therefore, although the authors called this pain scale an NRS, strictly speaking it is a composite SDS. Subsets of behaviour categories can be grouped together to yield a gross pain behaviour score, a posture score and a socialisation score. The NRS agreed with time budget analyses in that, post-surgery, horses consistently had higher scores than anaesthesia only and control horses. The same NRS was subsequently used by Sellon et al. (2004) to measure the response of post-coeliotomy horses to a constant rate infusion of butorphanol, allowing a significant effect of treatment on postoperative behaviour to be detected. However, neither of these studies verified inter-observer reliability of the NRS score.

Graubner et al. (2011) determined the inter-observer reliability of a multidimensional pain scale for post-abdominal surgery pain in horses, the ‘post abdominal surgery pain assessment scale’ (PASPAS; Table 7). PASPAS was reliable for assessment of post-coeliotomy pain (see Appendix: Supplementary Table S1), while behavioural indicators of pain correlated better with overall pain index than physiological parameters (heart rate and respiratory rate), indicating room for improvement in parameter selection and/or weighting. The value of including a ‘general subjective assessment’ is debatable, as this may in fact introduce more subjectivity and reduce inter-observer agreement of the PASPAS pain scoring system.

Preliminary work on use of the CPS by Bussières et al. (2008) in 94 horses with different clinical pain states (visceral and somatic pain) also included 13 post-operative colic cases (van Loon et al., 2010). Inter-observer reliability was excellent, leading the authors to conclude there was potential for use of the original orthopaedic CPS for visceral pain monitoring. An extension of that study examined post-operative pain after colic surgery in 48 horses and also found excellent inter-observer reliability of the CPS (van Loon et al., 2014). As survivors had significantly lower pain scores than horses that had to be euthanased or that had to undergo repeat laparotomy, monitoring of CPS scores could be of value in clinical decision making and assessment of the prognosis in the ICU.

Conclusions

Research on recognition and quantification of pain in horses has lagged behind similar work in humans, small animals and farm animals. In the past decade, this subject area has received formal attention, and large steps towards comprehensive and reliable multi-variable objective pain scales for use in various clinical applications have been taken. For further refinement and before routine clinical application is feasible, these scales will need to be validated ideally for each pain state to which they are to be applied. Reduction in the number of parameters in each composite scale by elimination of those variables that are least sensitive and specific for the pain state under study will further improve validity and reduce the time required for repeated observations. If performance of the equine facial expression pain scales proves to be equally good in clinical conditions (other than castration or after experimental nociceptive stimuli) they are likely to become very popular and valuable as pain monitoring tools for horses in clinical practice.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.tvjl.2015.07.030.

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