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Published in:
Comparative Exercise Physiology

Publication date:
2020

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Peer reviewed version

The final published version is available direct from the publisher website at:
[10.3920/CEP190049](https://doi.org/10.3920/CEP190049)

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Citation for published version (APA):

Tabor, G., & Williams, J. (2020). Objective Measurement in Equine Physiotherapy. *Comparative Exercise Physiology*, 16(1), 21-28. <https://doi.org/10.3920/CEP190049>

1 **Objective Measurement in Equine Physiotherapy**

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5

6 Conflict of Interest: None

7 Funding: None

8 **Abstract**

9 Objective measurement should be incorporated into all areas of physiotherapy including within
10 the assessment and treatment of horses, as there is a need to evaluate the effectiveness of
11 treatment intervention objectively. Whilst objective measures are available in a research
12 laboratory setting it appears that in clinical practice mostly subjective methods of recording
13 assessment and reassessment data are used. This article reviews the objective measures
14 currently available to equine physiotherapists for use in clinical practice, beyond those
15 available in a research laboratory setting. Within the literature there are studies reporting the
16 reliability and validity of objective measures for the assessment of pain, gait, posture, range of
17 motion, palpation and muscle size in horses. Whilst these validated objective measurement
18 tools are available, they are not presently used consistently in clinical practice. In addition, the
19 non-verbal nature of the equine patients precludes the use of self-reporting, meaning that there
20 are no reported functional outcome scores possible similar to use with human patients.
21 However the combined use of pain responses, behavioural changes and objective measures
22 collected during clinical assessment, both pre and post treatment, could be useful in practice.
23 Equine physiotherapists should integrate more objective methods of recording data from
24 assessments of horses.

25 Keywords: Equine, horse, objective, clinical practice, outcome measurement, reliability

26 Introduction

27 Equine Physiotherapists work within the team of professionals supporting both elite and leisure
28 horse populations, and are frequently involved in the management of musculoskeletal injuries
29 working in partnership with veterinarians (in some countries) (Tabor, 2018). Within human
30 practice, physiotherapy is an evidence-based profession (Chartered Society of Physiotherapy,
31 2017) and in order to achieve comparable professional practice standards into equine practice
32 there is a need to justify the intervention applied/physiotherapeutic treatment and evaluate its
33 effectiveness. Therefore Chartered Physiotherapists treating horses need to incorporate
34 objective measures (OM) into clinical practice (Bennell *et al.*, 1998). In the UK the CSP and
35 the Health and Care Professions Council (2013) (HCPC) states registrant (human)
36 physiotherapists *'must be able to assure the quality of their practice. This includes gathering*
37 *qualitative and quantitative data, participating in audit activity, using appropriate outcome*
38 *measures and evaluating interventions to ensure they meet service users' needs and changes in*
39 *health'*. When physiotherapists assess horses their aim is to reach a functional diagnosis that
40 identifies impairments and limitations to physical activities, compared with the veterinary
41 approach which usually would reach a pathoanatomical diagnosis (Goff, 2016; McGowan *et*
42 *al.*, 2007]. In the UK, according to the Veterinary Act (1966), the responsibility for diagnosis
43 lies with the veterinary surgeon however the clinical reasoning for a both veterinary and
44 physiotherapy assessment are the same (McGowan and Cottrill, 2016) and as such both should
45 include objective measurement within assessment of musculoskeletal conditions.

46

47 Patient reported outcome measures (PROM) have been shown to be reliable (repeatable) and
48 valid in human practice (Kyte *et al.*, 2015) with reliability being the extent to which repeated
49 measures yield consistent results, providing stable results that detect change in the actual value

50 and validity being whether the measure actually measures what it is supposed to measure
51 (Randle *et al.*, 2017). Within equine practice it is not possible to use direct PROMSs when
52 assessing outcomes of treatment of horses (Goff, 2016) as horse handlers, owners, riders and
53 trainers report on their observations or judgement of effectiveness of treatment, with their
54 views gathered as part of physiotherapist assessments subjectively. As in human rated PROM,
55 this may be subject to bias whereby an owner wishes to report either improvement or lack of
56 change in certain circumstances. Alternatively completion of a PROM (by the responsible
57 human for the horse) may be limited due to either lack of knowledge or simply poor
58 understanding of the horses' behavioural changes and clinical signs presenting as a result of
59 the musculoskeletal condition. To date, the use of PROMs reported by a proxy for the horse
60 has not yet been reported in either the scientific literature or the lay press.

61
62 Another approach to assessing change following treatment is to use outcome measures that do
63 not rely on a third party completing them, but instead are a direct outcome measure – also
64 known as objective measures (OBJM) (Goff, 2016). Measures of baseline for a variety of
65 variables such as range of motion, muscle strength or fitness can be recorded by the
66 physiotherapist and these scores can be monitored for change through the intervention phase
67 (treatment period) to assess progress and report on the final outcome of treatment. Comparison
68 of pre- and post-treatment data can be used to determine the effectiveness of a given treatment
69 therefore the usefulness of the chosen intervention (treatment) and potentially increasing the
70 evidence-base for the treatment/intervention applied.

71
72 According to a recent survey of equine physiotherapists (Tabor and Williams, 2018) over 80%
73 reported to use OBJM, however the measures used were mainly subjective, such as visual
74 assessment of lameness, palpation and muscle symmetry. Respondents identified the lack of

75 validated measures available to clinicians as a primary reason for not using OBJM. There was
76 also a perception that measures reported in the veterinary literature are difficult to use and time
77 consuming. For example, in the laboratory setting the thorough study of forelimb and hindlimb
78 kinematics and kinetics (Clayton and Back, 2013a; Clayton and Back, 2013b) has increased
79 understanding of equine locomotion using gold standard, objective methods of data collection,
80 such as three-dimensional analysis with digital optical motion capture systems and force plates
81 to capture ground reaction forces (Clayton and Schamhardt, 2013). However in reality the
82 equipment required to carry out these assessments is expensive, difficult to move around, and
83 requires time to calibrate and to process data, so are not routinely used in clinical physiotherapy
84 practice.

85

86 The aim of this paper is to review OBJM that could be used in clinical practice, rather than in
87 a laboratory or research setting, by physiotherapists whilst treating horses.

88

89 In addition to referring to a core Animal Physiotherapy textbook (Goff, 2016) a literature search
90 was performed in Science Direct, Wiley Online databases and Google Scholar using the
91 following keywords in various combinations: 'equine', 'horse', 'physiotherapy',
92 'rehabilitation', 'measure', 'objective', 'outcome' within date range 1990 – 2019. The titles
93 and abstracts of the retrieved studies and those not relevant were discarded with the reference
94 lists of the selected articles searched for additional references. Articles found were categorised
95 into sections relating to measurement area and reviewed: pain assessment in horses; gait
96 assessment; spinal posture and range of movement; goniometry; palpation and muscle size.

97

98 **Pain assessment in horses**

99 The recognition and management of pain is crucial to the welfare of horses (Dalla Costa *et al.*,
100 2014) however there is very little published research into scales to assess pain in horses
101 (Gleerup *et al.*, 2015) although it is known that the ability of the observer to recognize pain
102 influences the efficacy of subjective pain scales (Bussieres *et al.*, 2008). There are multiple
103 measures used to assess musculoskeletal pain in humans, many based on verbal reports to
104 document quantity (intensity) and quality as well as the pain experience, and how these effect
105 function, sleep and mood for example (Hawker *et al.*, 2011). However, pain assessment in
106 animals is limited due to lack of self-reporting and reliance on observation of behaviours
107 reportedly associated with pain (Dyson *et al.*, 2018). Detection of pain by changes in
108 physiological markers, behaviour (Bussieres *et al.*, 2008) and in facial expression have been
109 suggested as proxy measures for pain in animals (Dalla Costa *et al.*, 2014; Gleerup *et al.*, 2015).
110 The Horse Grimace Scale (HGS) has been developed and validated as a practical tool to assess
111 post-operative pain (Dalla Costa *et al.*, 2014). The HGS uses observation of horse behaviour
112 and facial expression, through a three point scoring system of scoring six Facial Action Units
113 (stiffly backwards ears, orbital tightening, tension above the eye area, prominent strained
114 chewing muscles, mouth strained and pronounced chin and strained nostrils). Based on high
115 inter observer reliability and correlation with composite pain scores when tested in horses
116 following castration, the authors suggest that the HGS may be of use in other clinical scenarios.
117 A second research group quantified an ethogram based on the presence or absence of certain
118 behaviours and facial expressions in horses prior to and after application of a noxious stimuli
119 (Gleerup *et al.*, 2015). As per Della Costa *et al.* (2014), Gleerup *et al.* (2015) indicated that
120 facial expressions (change in ear position and appearance of eyes, nostrils and lips) were
121 exhibited during periods of pain, and named this the Equine Pain Face (EPF). To further
122 validate the HGS as a specific tool to assess pain Dalla Costa *et al.* (2017) attempted to
123 investigate if emotional states effect the score, and suggested that positive and negative

124 emotional states did not differ from control HGS. Both studies of facial expression as well as
125 previously validated studies of composite pain score (Bussieres *et al.*, 2008; Dalla Costa *et al.*,
126 2014; Glerup *et al.*, 2015) assess behaviour in response to acute pain. Change in behaviour
127 for chronic pain has yet to be fully investigated, so the HGS and EPC may not be reliable
128 indicators of this type of pain, so caution must be applied when attempting to assess chronic
129 pain with these scoring systems.

130 The HGS and EPF are used in assessments of the unriden horse, however most horses are also
131 expected to perform under saddle therefore ethograms for assessing pain in ridden horses have
132 been developed (Dyson *et al.* 2017; Dyson *et al.* 2018; Mullard *et al.*, 2017). Facial expressions
133 in ridden horses (FEReq) were assessed and found repeatable when categorising horses as lame
134 or not lame from photographs (Mullard *et al.*, 2017). In a larger scale study (Dyson *et al.* 2017)
135 519 photographs of ridden horses were analysed and the FEQeq score for lame horses was
136 significantly higher than those for non-lame horses. In a small sub-group of horses that had
137 received diagnostic analgesia to abolish pain significant differences in FEReq were identified
138 before and after administration of medication. The authors did highlight limitations of
139 assessment of pain from facial expression and have gone on to assess an ethogram that included
140 the FEReq and whole-horse behaviours (Dyson *et al.*, 2018). Observers using this revised
141 scoring system recorded significant difference in mean occurrence of behaviours in non-lame
142 horses when compared to lame horses. It was established from this that the occurrence of eight
143 of more markers, from a list of 24 behavioural descriptors suggests musculoskeletal pain.
144 There is a clear need for objective pain assessment in clinical cases due to its impact on equine
145 welfare (van Loon and van Dierendonck, 2019), consequently a combination of whole-horse
146 behaviours and facial expression assessment could be utilised within physiotherapy assessment
147 of pain in horses.

148

149 **Gait Assessment**

150 Evaluation of a horse's gait forms part of the systematic approach to the physiotherapy
151 assessment procedure (Goff, 2016), however, it is the role of the veterinarian to establish
152 whether there is an underlying pathological condition or not (i.e. provide diagnosis) as stated
153 in the 2015 Exemptions Order of the Veterinary Act (1966) in the UK. If an irregularity or
154 asymmetry is present it may or may not be considered a subclinical sign of lameness (Bragança
155 *et al.*, 2018). There is considerable variation in scoring lameness between veterinarians (Fuller
156 *et al.*, 2006; Keegan *et al.*, 2010) reducing the reliability of both inter-tester and test-retest
157 measures by observation only. No published data on the ability of physiotherapists to assess
158 gait exists.

159 A physiotherapist conducting a gait assessment may focus on assessing gait with a view to
160 assess function of the neuromusculoskeletal system in addition to observing for lameness.
161 Optimal movement is achieved through correct timing and co-ordination of muscle activity, as
162 well as proprioception and balance. The ability for the musculature to control the limb
163 movements based on a trunk that is dynamically stable is also required (Pfau *et al.*, 2017).
164 Inertial Motion Unit (IMU) technology has been used to assess the limb and spinal motion
165 (Bragança *et al.*, 2018) and measure the effects of a four week period of training period (Pfau
166 *et al.*, 2017) however, as yet, no studies have used IMUs to objectively measure the effect of a
167 physiotherapy intervention. Equine spinal motion has also been assessed in unriden horses
168 with and without lameness, on straight lines and on circles (Greve *et al.*, 2015a; Greve *et al.*,
169 2015b). In addition at present there is debate within the veterinary community regarding what
170 constitutes clinical lameness, potentially caused by pathology and what may be a non-limiting
171 gait asymmetry (Van Weeren *et al.*, 2017). Although asymmetry can be measured, this
172 information not conclusive until the relationship between performance, pain and the threshold
173 for abnormal asymmetry is determined. In addition, whilst the use of IMUs contributes to the

174 understanding of normal and abnormal kinematics, the set up and use of IMUs in daily clinical
175 practice is yet to be commonplace.

176 **Spinal Posture and Range of Movement**

177 Spinal range of motion is often evaluated in equine musculoskeletal assessments. The cervical
178 spine range of movement can be observed using a food bait to encourage the horse to move
179 their head around to one side of the body, then to the other, to assess range of lateral flexion
180 (Clayton *et al.* 2012) and forward to the chest or between the front legs (Clayton *et al.*, 2010),
181 to assess cervical and thoracolumbar flexion. Manually induced reflexes to stimulate muscle
182 contraction to create spinal motion in the thoracolumbar and lumbosacral regions are also used
183 (Goff, 2016; Licka and Peham, 1998). Spinal motion assessed by both baited and reflex
184 induced mobilisations are assessed subjectively in terms of range and quality of movement
185 (Tabor and Williams, 2018). Recording movement via video footage however does allow for
186 post-assessment objective analysis of posture (Tabor *et al.*, 2019; Taylor *et al.*, 2019) and range
187 of movement (Taylor *et al.*, 2019), although only subjective rating of posture is reported to
188 occur in practice (Tabor and Williams, 2018). Lesimple *et al.* (2012) found that there is a
189 correlation between pain and posture during standing or during ridden exercise which is based
190 on cervical spine position in horses that have a diagnosis of back pain in the thoracolumbar
191 region. Achieving standardisation of body position is critical for comparing pre- and post-
192 treatment/intervention measurements. In the horse, the standing position is considered to be
193 repeatable when the horse is stood 'square' (lay terminology) and the plantar aspect of each
194 metatarsus perpendicular to the ground, aligned with tuber ischii (Routh *et al.*, 2017). The use
195 of reliable and repeatable methodologies are needed to be able to validate measurements
196 techniques (Heale and Twycross, 2015).

197 **Goniometry**

198 Whilst kinematic analysis can provide data on joint range of motion during gait (Clayton and
199 Back, 2013a; Clayton and Back, 2013b), in clinical practice goniometry can be used to
200 objectively assess joint motion, allowing evaluation of treatment intervention and outcome. A
201 goniometer is a simple and inexpensive device commonly used in physical therapy and in
202 horses (Adair *et al.*, 2016; Alrtib *et al.*, 2015; Liljebrink and Bergh, 2010) and has been
203 validated against 'gold-standard' radiography. It has been shown to have high intra-tester
204 reliability and low (Liljebrink and Bergh, 2010) or high average inter-tester reliability (Adair
205 *et al.*, 2016), potentially due to variation in identifying the anatomical landmarks used and
206 therefore the positioning of the goniometer between each assessor. Consistency in standing
207 position (Alrtib *et al.*, 2015), similar to the requirement when assessing posture (Routh *et al.*,
208 2017; Tabor *et al.*, 2019), use of an assistant and whether the horse is standing or anaesthetised
209 in lateral recumbency (Liljebrink and Bergh, 2010) should be taken into account if repeated
210 measures are to be reliable. To date, the reliability of goniometry has not been tested in a
211 longitudinal study in horses. Therefore in clinical practice, to ensure confidence in repeated
212 measures it is recommended that the same observer measures the joint angle with a goniometer
213 on repeated occasions.

214 Range of motion of the cervical spine (distance of the horse's nose to shoulder) has also been
215 proposed as a useful OBJM (Goff, 2016), however neither the reliability nor validity of this
216 method have been tested in the horse.

217 **Palpation**

218 Clinical evaluation of musculoskeletal pain has traditionally included assessment by palpation,
219 however its subjectivity limits its strength as a clinical or research outcome score (Varcoe-
220 Cocks *et al.*, 2006). A pressure algometer (PA) (a handheld device), has been used to attempt
221 to objectively measure pain response in horses during palpation (De Heus *et al.*, 2010; Haussler

222 and Erb, 2006a; Haussler and Erb, 2006b; Menke *et al.*, 2016; Varcoe-cocks *et al.*, 2006). A
223 PA uses a calibrated pressure gauge with an attached plunger that is pressed against the body
224 (Figure 1). To assess repeatability, Haussler and Erb (2006a) conducted a number of
225 experiments to assess the PAs value in differentiating the mechanical nociceptive threshold
226 (MNT) in areas of known pain versus pain-free regions. The MNT refers to the specific point
227 at which a physiological or behavioural response is noted, during the application of a
228 quantifiable stimulus to a certain area of the body (Love *et al.*, 2011). During the application
229 of a PA, this threshold can be documented by recording the force (kg or N) being applied at
230 this point. The MNT were higher over the spinous processes in the thoracolumbar region
231 compared to over the temporomandibular joint for instance (Haussler *et al.*, 2006a). In this
232 study 62 sites were tested three times each to establish repeatability, in 36 horses, with
233 sequential increases in MNT in 24% of subjects showing adaptation to the pressure being
234 applied, whilst 8% became more sensitised to the pressure. However the median range was
235 1kg/cm² which the authors note as their suggested measurement error, requiring a change of
236 +/- 1kg.cm² to be used to assess for change in response to palpation. A further test of PA
237 repeatability, in 12 thoroughbred racehorses by Varcoe-cocks *et al.* (2006) found that the PA
238 scores, as well as being repeatable in four thoracolumbar and pelvis points, correlated with
239 subjective scores of muscle palpation. PA appears to provide an objective repeatable clinical
240 measure of MNTs, and therefore could be used to assess the therapeutic effectiveness of an
241 intervention /physiotherapy treatment.

242

243 [Figure 1]

244

245 Multiple palpation scoring systems are used in human physiotherapy (Hawker *at al.*, 2011) to
246 help the clinician understand pain levels, but they are subjective scales based on the verbal

247 feedback given by the human patient. In the equine field, self-reporting is not possible therefore
 248 palpation scoring scales have been established (De Heus *et al.*, 2010; Varcoe-cocks *et al.*, 2006)
 249 that rely on scoring by a third party, usually the owner / keeper or rider (Table 1). These scoring
 250 systems can be used to score pain, tissue texture and behaviour responses and range from
 251 detailed systems which are less open to subjective bias to more basic systems such as the scale-
 252 based approach (normal, mild, medium) used by Jepsen *et al.* (2006) to record
 253 mechanosensitivity on palpation. In a recent study excellent inter-rater reliability was found
 254 between three qualified veterinary physiotherapists when manually assessing epaxial soft tissue
 255 using a palpation score and agreement was greater for manual palpation than a PA or an
 256 electronic force sensor (Merrifield-Jones *et al.*, 2019). In clinical practice detailed scales tend
 257 not to be utilised (Tabor and Williams, 2018) and worryingly, use of subjective or no scales,
 258 could result in significant subjective interpretation and variability between clinicians.

259

260 Table 1: Example of palpation scoring scale, modified from Varcoe-Cocks *et al.* (2006) and
 261 the Modified Ashworth Scale (Ravara *et al.* 2015).

262

Score	Description
0	Soft, low tone
1	Normal
2	Increased muscle tone but not painful
3	Increased muscle tone and/or painful (slight associated spasm on palpation, no associated movement)
4	Painful (associated spasm on palpation with associated local movement, i.e. pelvic tilt, extension response),

5	Very painful (spasm plus behavioural response to palpation, i.e. ears flat back, kicking).
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263

264

265 **Muscle size**

266 A fundamental component of physiotherapy includes rehabilitation programmes that prescribe
267 exercise for therapeutic purposes. Developing muscle strength (skeletal muscle hypertrophy)
268 is one adaptation often desired within rehabilitation (Schoenfeld *et al.*, 2016). An example in
269 this context would be exercises prescribed to address muscle atrophy of the thoracic paraspinal
270 muscles related to back pain (muscle soreness) caused by saddles (Von Peinen *et al.*, 2010).

271 Cross sectional area (CSA), measured by ultrasonography has been used to record muscle size
272 change (de Oliveira *et al.*, 2015; Stubbs *et al.*, 2015) in the multifidus muscles in the
273 thoracolumbar spine plus thickness of the longissimus dorsi muscle has also been shown to be
274 repeatable (Abe *et al.*, 2012). However access to the equipment needed for this measurement
275 purpose, plus the requirement in horses for removal of hair which would otherwise trap air and
276 impact imaging, is likely to restrict the use of ultrasonography to provide outcome measures in
277 clinical practice.

278 Greve and Dyson (2014) have reported the use of a flexible curve ruler (FCR) to provide data
279 on the shape and symmetry of the thoracic spinal profile finding a positive association between
280 saddle slip and horses with a wider back shape at the 13th thoracic vertebrae compared with
281 that at the 18th. In a subsequent study the FCR was used to measure longitudinal back
282 dimension changes at two month intervals over one year (Greve and Dyson, 2015). Changes
283 in shape and symmetry were related to factors associated with the horse, the saddle and rider.
284 Therefore the FCR could be reliably used to assess for paraspinal muscle hypertrophy (or

285 atrophy) as a result of a physiotherapy intervention. FCR of the profile at the 16th thoracic
 286 vertebral level has also been tested against CSA of *multifidus* however there appears to be no
 287 relationship between the size of this deeper stability muscle and the transverse profile (Tabor,
 288 2015), suggesting the FCR is useful for a gross record of a region but not specific to individual
 289 muscle change.

290

291 **Current use of objective measures in equine physiotherapy**

292 There is evidence to support the reliability of individual OBJM, however inter-rater reliability
 293 is not a high as intra-rater reliability indicating that the use of tools and techniques to collect
 294 objective measurement could be used by individual practitioners confidently but with caution
 295 for multiple users. Despite this, even the use of these tools is reported to be limited by
 296 individual equine physiotherapists and to aid evaluation of interventions/physiotherapy
 297 treatments practitioners should select the most appropriate and reliable tool for the assessment
 298 requirement (Table 2).

299

300 Table 2: Summary of objective measurement tools evaluated for use in equine
 301 musculoskeletal assessment

Measure	Tool and purpose	Pros (✓)/ Cons (X)	Supporting Evidence
Range of Motion	Tape measure: Cervical spine lateral flexion – nose to landmark on trunk	✓ Simple ✓ Inexpensive X Reliability not tested	Clayton et al. (2010); Clayton et al. (2012); Goff (2016)
	Goniometry: Limb joint flexion and extension	✓ Simple ✓ Inexpensive X Peripheral joints only X low inter-rater reliability	Liljebrink and Bergh, 2010; Alrtib <i>et al.</i> , 2015; Adair <i>et al.</i> , 2016;
Posture	Photographs: Static spinal posture	✓ Simple ✓ Inexpensive X low inter-rater reliability X Computer software required	Lesimple <i>et al.</i> (2012); Tabor and Williams (2018)

	Video: Spinal posture from individual frames	✓ Inexpensive X Inter-reliability not tested X Computer software required	Taylor <i>et al.</i> (2019)
Palpation	Palpation score: Pain (behavioural) response / muscle tone / spasm	✓ Simple ✓ Inexpensive ✓ Excellent inter-rater reliability X Categorical scoring	Varcoe-cocks <i>et al.</i> (2006); De Heus <i>et al.</i> (2010); Merrifield-Jones <i>et al.</i> (2019)
	Pressure Algometry: Mechanical nociceptive threshold	✓ Simple ✓ Inexpensive X Inconsistent inter-rater reliability reported	Varcoe-cocks <i>et al.</i> (2006); Haussler and Erb (2006a); Haussler and Erb, (2006b); Menke <i>et al.</i> , 2016;
Muscle size	Flexicurve Ruler: Transverse profile of thoracolumbar spinal region	✓ Simple ✓ Inexpensive X Gross bulk measurement not individual muscles	Greve and Dyson (2014 & 2015)
	Ultrasound Scan: Muscle cross sectional area	✓ Reliable ✓ Measurement of individual muscles X Expensive equipment X Specialist training required	Abe <i>et al.</i> (2012); de Oliveira <i>et al.</i> (2015); Stubbs <i>et al.</i> (2015)

302

303

304 **Future use of objective measures in equine physiotherapy**

305 Within a physiotherapy assessment there is a requirement to use OBJMs and whilst factors
306 such as muscle strength cannot be tested, in future the advances of technologies may allow the
307 use of proxy measures in the clinical situation. Adopting proven practice from musculoskeletal
308 assessment and physiotherapy management within human medicine is recommended for
309 equine welfare and for professional practice. This would improve the support for certain
310 treatments or rehabilitation interventions, for instance manual therapies, electrotherapies or
311 exercise programmes. Studies investigating the efficacy of animal rehabilitation /
312 physiotherapy inventions currently being used should examine and scrutinize the

313 methodologies and the appropriateness of outcome measures used. For the profession to
314 continue to work within the construct of increased requirement for evidence based practice,
315 clinicians need to adopt a more widespread use of truly OBJMs. Use of reliable and valid
316 measurements will strengthen the evidence base for the use of physiotherapy and rehabilitation
317 in practice.

318

319 **Conclusion**

320 Validated outcome measures are needed to support clinical reasoning in selection of
321 physiotherapy approaches to treated horses and to provide evidence of effectiveness. Whilst
322 there are validated tools available at present (e.g. goniometry and palpation scores), these are
323 not in consistent use in clinical practice. The challenges of a non-self-reporting patient should
324 be taken seriously and the combined use of pain responses, behavioural changes and objective
325 measures collected during assessment could be considered useful in practice once further
326 validation of these has been conducted. Further development of existing measures in
327 conjunction with validation studies of outcome scoring systems could enhance clinical equine
328 physiotherapy practice.

329 Ethical Approval: None required

330 Funding: This research did not receive any specific grant from funding agencies in the public,
331 commercial, or not-for-profit sectors.

332 Conflict of Interest: None

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