

# 1 Physiotherapy for neck pain in the horse

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5

## 6 Abstract

7 The aim of this review is to present the physiotherapy approach to assessment and treatment of neck  
8 pain in horses, supporting veterinary care as part of a multi-disciplinary team. Horses with neck pain  
9 form a high percentage of veterinary physiotherapists' caseload and physiotherapists are trained in  
10 specific assessment strategies to identify functional limitations in this region. After investigation and  
11 veterinary intervention, physiotherapy care can address factors such as pain, reduced range of motion  
12 and muscle weakness. Through the selection of appropriate manual therapy techniques and  
13 prescription of therapeutic exercises, a physiotherapist can assist restoring function and performance  
14 in the cervical region. Physiotherapy treatment of the neck should occur, along with consideration of  
15 the whole horse's musculoskeletal function, to support the veterinary medical or surgical intervention.

16

## 17 Introduction

18 The head and neck of the horse have a highly specialised structure to allow for the function of the  
19 region (Zsoldos and Licka 2015). Evolved to avoid predation, a horse in the grassland plains needed a  
20 long neck to reach the ground, due to lengthened limbs aiding fast movement. The recognition of a  
21 potential threat needed the horse to be able to switch from grazing to surveying the horizon and then  
22 high-speed locomotion almost in an instant. There is considerable variation in cervical anatomy  
23 between the cranial, mid and caudal regions which enables the range of movement but maintains  
24 stability and the neuromuscular control of this motion. It is not a surprise that the management of  
25 horses with head and neck pain and dysfunction was listed as the most common area for  
26 physiotherapy care, following back and pelvis region issues in a recent survey of veterinary  
27 physiotherapists (Tabor, 2020a). The aim of this review is to present the physiotherapy approach to  
28 assessment and treatment of neck pain in horses, supporting veterinary care as part of a multi-  
29 disciplinary team.

30 The anatomy of the equine cervical spine has been described with the structure of the vertebrae  
31 detailed, however knowledge of the anatomy of the head and neck region has expanded in the last  
32 decade with both necropsy, radiography, magnetic resonance and computed tomographical studies  
33 (Sleutjens et al 2014; Haussler et al 2019; Lindgren et al 2020). These imaging techniques have allowed  
34 visualisation of anatomic variation in horses with pathology and those considered to have normal  
35 anatomy. The absence of unilateral or bilateral absence of the C6 caudal ventral tubercle was  
36 discovered in 19 of 50 thoroughbred horses examined at post-mortem (May-Davis 2014) and in 79 of  
37 81 modern horses the nuchal ligament lamellae did not attached onto C6 or C7 (May-Davis et al 2018).  
38 May-Davis and colleagues consider that these findings may be considered a contributing factor in  
39 caudal cervical osteoarthritis (OA) however no longitudinal studies of the relationship between nuchal  
40 ligament anatomy and pathology have been conducted and interestingly Veraa et al (2019) did not  
41 find a positive relationship between morphologic variations and clinical signs. Rombach et al (2013)  
42 and Haussler et al (2019) have shown that OA is symmetrically present with higher severity in the mid  
43 to caudal cervical regions and with higher prevalence in older and larger horses which would have

44 relevance to sport horse populations. The presence of cervical facet OA should be considered in  
45 horses with neck pain, especially warmbloods training in dressage who present with neck muscle  
46 atrophy, neck stiffness, forelimb or hindlimb lameness, stumbling, neck and/or back pain as well as a  
47 reluctance to work (Koenig et al. 2020). These clinical signs could be a reason for referral to a  
48 physiotherapist. In contrast horses with neurological signs such as spinal ataxia and upper motor  
49 neuron paresis, will have compression of the spinal cord of the cervical spine and are unlikely to be an  
50 appropriate candidate for physiotherapy, which may indeed be contraindicated. This compression  
51 may be caused by conditions such as cervical vertebral stenotic myelopathy (Nout and Reed 2003).  
52 Horses seen to have episodes where they are unable to raise the head from an abnormally low  
53 position, fixed below the level of the carpus, as described by Down and Henson (2009), require  
54 veterinary investigation prior to consideration for referral for physiotherapy. Additionally, the  
55 presence of bony injury such a cervical fracture must also be excluded before physiotherapy (Rossignol  
56 et al 2016). Horses with wing of atlas fracture, one from a fall whilst point to point racing and one  
57 tripping whilst being lunged with a rope training aid on, have formed part of the author's caseload in  
58 the last twelve months. Reports of avulsion fracture of the nuchal crest with nuchal ligament desmitis  
59 have highlighted that the cause of head-shaking and neck pain should be fully investigated (Voigt et  
60 al. 2009). If there is a history of an incident such as a fall, collision or blunt trauma, which could be  
61 the result of the horse elevating the head suddenly and making contact with the top of the stable door  
62 frame, bone injury should be considered and excluded prior to physiotherapy.

63 Primary muscle injuries within the neck region are a likely of cause of pain however consideration of  
64 these seem to be underrepresented in the current literature. Whilst traumatic muscle lesions, due to  
65 strain and subsequent muscle fibre tearing and inflammation, can occur in any region of the body,  
66 observation of the kinematics of horse falls, especially at speed, reveals that the muscles are taken  
67 beyond their normal physiological range, exposing them to risk of muscle tears (figure 1). In addition  
68 to acute overload, chronic overload created due to overuse as a result of poor muscle strength,  
69 recurrent abnormal movement patterns or poor training and recovery planning, could also cause  
70 muscle pain in the epaxial and/or hypaxial cervical muscles.



71

72 Figure 1: Horse falls can result in bone and soft tissue injury. Even without bone injury, neck pain can  
73 be caused from the extreme positions that creates a movement force, beyond the normal  
74 physiological range, that overloads the soft tissues (Muscles, ligaments, neural and fascial).

75

76 Physiotherapy

77 Physiotherapy helps restore movement and function when an individual is affected by injury, illness  
78 or disability (Chartered Society of Physiotherapy [CSP], 2020) with treatments structured around the

79 goal of restoration of painless optimal function as well as prevention of loss of function (McGowan et  
80 al, 2007). Physiotherapy includes treatments such as manual therapy, use of electrophysical  
81 modalities and exercise prescription, as well as encompassing on-going rehabilitation. In the context  
82 of musculoskeletal conditions, rehabilitation focusses on building capacity in tissues, using gradual  
83 overload, progressing intensity and complexity of movement or physical activity (Cook and Docking  
84 2015).

85 Training to become a Chartered Physiotherapist requires a three-year undergraduate degree and to  
86 become a veterinary physiotherapist and category A member of the Association of Chartered  
87 Physiotherapists in Animal Therapy (ACPAT), a minimum of two years post graduate training at UK  
88 Higher Education level 7 (Masters degree) is required. It should be noted that in the UK in relation to  
89 treating animals the term physiotherapist is not a protected title, therefore currently 'physiotherapy'  
90 for horses can be provided by any member of the public regardless of their level of training. To  
91 ascertain the standard of training of an individual it is recommended to refer to  
92 an independent voluntary register such as the Register of Animal Musculoskeletal Practitioners  
93 (RAMP).

94 Physiotherapy is listed as a treatment in the Veterinary Surgeons Act (Exemptions) Order 2015 (UK  
95 Government, 2020) and within the Code of Professional Conduct of Veterinary Surgeons (Royal  
96 College of Veterinary Surgeons, 2019). It is therefore imperative that physiotherapists follow the law,  
97 working under the direction of veterinary surgeons, who must ensure the health and welfare of  
98 animals committed to their care and to fulfil their professional responsibilities

#### 99 Physiotherapy assessment

100 Physiotherapy assessment of the neck region should take the subjective information gained from the  
101 owner and/or rider, forward to observation of static posture and active movement during a gait  
102 assessment. Head and neck posture in both both standing and dynamic conditions, in hand, on  
103 straight lines and the lunge, as well as ridden if appropriate, should be assessed. This will give an  
104 indication of longer term movement patterns and posture, acutely abnormal posture and neck  
105 position as well as the function of the neck during the movements witnessed. At this time both facial  
106 expressions (Gleerup et al. 2015) and whole horse behaviours should be noted to assess for signs of  
107 pain (Dyson et al. 2018). Further assessment should evaluate muscle development, the response to  
108 soft tissue palpation and cervical vertebral range of motion from the atlanto-occipital joint to the  
109 cervicothoracic junction. Baited stretches can be used to induce joint motion and can highlight pain  
110 and stiffness which can be a clinical sign of osteoarthritis of the cervical spine (Koenig et al 2020). On  
111 palpation pain may be displayed via behaviour signs such as aversive behaviours of the head and neck,  
112 e.g. withdrawal responses (head toss, bite threat; Rombach 2013) which should be recorded using an  
113 objective method such as a palpation scoring system. There are no published validated scoring  
114 systems for the cervical region but use of categorical scoring of responses similar to that used in the  
115 thoracolumbar region (Merrifield et al. 2019; table 1) would provide a more objective record as would  
116 pressure algometry (Haussler and Erb 2006).

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).

117 Table 1: Categorical scoring system used to document response to palpation. It is important to note the name  
118 and location within the specific muscle or region being palpated with the score.

119 In addition to pain, cervical arthropathies can cause altered muscle size, including atrophy and  
120 asymmetry (Koenig et al 2020; Dyson 2011). Clinical signs arising from the neck region should be  
121 considered along with the whole-body assessment. Neck pain may be because of gait changes due to  
122 a primary limb lameness where asymmetric head and neck motion is a compensatory strategy to  
123 reduced vertical force through a limb (Zsoldos and Licka 2015). Riders' anecdotally describe ridden  
124 horses 'reefing' at the reins, described as pulling the reins out of the rider's hands by taking the head  
125 forwards and out, combined with either elevation of lowering the head, which can be associated with  
126 the presence of back pain. During observation of training practices in the ridden horse, postures such  
127 as the use of a hyperflexed neck or high neck position might result in altered motion of the whole  
128 spine thus it is critical to assess the whole horse (Rhodin et al 2009).

129 If there are unexpected or worsening signs of neurological deficit, demonstrated by a reduction in  
130 limb proprioception, forelimb lameness or subtle hindlimb gait abnormalities, all of which are listed  
131 as potentially resulting from a compressive lesion of the spinal cord by Dyson (2011), the horse should  
132 be referred back to the veterinary surgeon. Neck dysfunction may be found during a routine  
133 physiotherapy assessment of the whole horse (Tabor 2020b). However, following diagnosis and  
134 veterinary intervention physiotherapy can be clinically reasoned to be appropriate to restore function  
135 and rehabilitate the horse back to optimal performance.

### 136 Physiotherapy treatment

137 Physiotherapy treatment may commence immediately following initial assessment, or at a later date,  
138 following veterinary intervention. For example, cervical facet OA might be treated by intra-articular  
139 injections of corticosteroids (Koenig et al. 2020) and after a short period of rest, physiotherapy would  
140 be indicated to assist return to function.

141 Manual therapy for neck pain is an option for pain relief and restoration of function. Bishop et al.  
142 (2015) define this as passive, skilled movement applied by clinicians that directly or indirectly targets  
143 a variety of anatomical structures or systems, used to create beneficial changes. These authors discuss  
144 that although historically joint mobilisations and manipulations as a form of manual therapy, were  
145 previously considered to alter position of articular structures, modern understanding to support the  
146 mechanism of effect is that the action of the mobilisation or manipulation modulates pain via  
147 neurophysiological factors. Manual therapy techniques that are directed at muscles and connective  
148 tissue, with massage and myofascial release being commonly reported in the lay media, would likely  
149 have a similar mode of action. Evidence for structural changes in tissues as a result of soft tissue  
150 therapy is lacking but certainly effects on hormonal levels, para-sympathetic activity system and blood  
151 flow have been reported (Weerapong et al. 2005). The resultant modulation of pain may allow for a  
152 change in muscle and joint function. If there is muscle spasm limiting movement or arthrogenic  
153 inhibition that is reducing muscle activity and power, the applied joint mobilisations and soft tissue  
154 treatments are aimed at returning to a more normal motor pattern. Change in the overlying muscle

155 function plus reduction in joint pain would reduce the stiffness of the region and aid restoration of  
156 range of motion.

157 Joint mobilisations can be performed within the physiological range of motion or within the accessory  
158 range. Physiological range refers to joint motion that can be accessed actively by the patients own  
159 muscular activity within normal anatomic limits and therefore is flexion, extension, lateral flexion and  
160 rotation (Haussler, 2009). Accessory ranges are the gliding and rolling motions that occur during joint  
161 motion and during mobilisations pressure, via manual force, is used to induce these movements  
162 passively.

163 A technique that the author applies in the cervical region is to use a passively applied force to the joint  
164 whilst an active physiological movement occurs, termed a mobilisation with movement. An example  
165 to increase lateral flexion would be to apply a manual force to the left mid portion of the neck over  
166 the transverse process of C3 and use bait to induce active left side flexion. The hand on the neck  
167 provides a lateral accessory glide, and a fulcrum for the region cranial to the hand to move around.  
168 The hand can then be sequentially moved caudally as more lateral flexion is asked for with the bait.  
169 The resultant effect is a larger and improved quality (less stiff) range of lateral flexion when baited  
170 movements are used to re-assess lateral flexion.

171 The inability to measure patient expectations and outcomes directly from the horse may be the reason  
172 for the limited empirical and scientific research into equine manual therapy compared to human  
173 studies, however their effect on spinal mobility and limb kinematics have been used to objectively  
174 record outcomes. Spinal manipulative therapy in the thoracolumbar region did increase dorsoventral  
175 displacement compared to a control group (Haussler et al. 2010) and had short term increase in  
176 flexion-extension movements between T10 to L1 (Alvarez et al. 2010). However, there are no studies  
177 measuring kinematics following similarly applied treatments to the cervical spine. Massage of the  
178 muscles in the equine hindlimb increased the passive range of protraction (Hill and Crook 2010) and  
179 although the exact mechanisms are unclear, based on the current understanding of the effects of  
180 massage (Weerapong et al. 2005), the resultant change in range of motion is likely to be from  
181 neurological modulation of factors that may be limiting range of motion in the first place.

182 Behavioural response to palpation can be measured objectively via by trained assessors with a tool  
183 called a pressure algometer and the threshold before the horse demonstrated nociception, where the  
184 pressure applied is considered to be felt as painful, can be used to evaluate effects of treatment. In a  
185 study of 38 horses divided into five groups of treatment or control, horses that had instrument assisted  
186 chiropractic treatment and therapeutic massage to the thoracolumbar regions did show a raised  
187 nociceptive threshold (Sullivan et al. 2008). These results further support the use of manual therapy  
188 in treatment of horses.

189 Whilst there is a lack of studies reporting on the outcomes of manual therapy in the equine neck  
190 extrapolating from effects in the thoracolumbar region, it can be reasoned that as manual therapy has  
191 been shown to reduce pain and improve flexibility (Haussler 2010), it should also be advocated for use  
192 in the cervical region. The effects of manual therapy have only been demonstrated in the short term,  
193 therefore interventions to ensure ongoing management and maintenance of a state of reduced pain  
194 and increased range of motion should be considered. In human treatment a multimodal approach,  
195 which includes manual therapy, exercise and education, seems to provide better outcomes than  
196 manual therapy alone (Bishop et al. 2015). Therefore, specific therapeutic exercise that target the  
197 cervical region should be included within care of horses with neck dysfunction.

198 In the thoracolumbar spine osseous pathology is associated with atrophy of the *m. multifidus* which  
199 has a role as a stabiliser of the vertebral segments. In human patients the cross-sectionally area of *m.*  
200 *multifidus cervicis* has been shown to be smaller than in non-painful controls (Fernández-de-las-Peñas  
201 *et al.* 2008) and the size of *m. longus colli* altered in patients with chronic neck pain (Javanshir *et al.*,  
202 2011). Rombach (2013) established a reliable method, using ultrasound imaging, to measure the *m.*  
203 *multifidus cervicis* and *m. longus colli* cross sectional area and it could be reasoned that these muscles  
204 would reduce in size in the presence of pain in horses. *M. longus colli* provides sagittal plane  
205 intersegmental vertebral column stability therefore, as a deep stabiliser muscle, is likely to be subject  
206 to the same atrophic pattern as *m. multifidus*. Therefore, restoration of strength and resultant  
207 function of these deeper muscles which have shorter, slow-oxidative fibres that are more fatigue-  
208 resistant to provide segmental stabilization between individual joints, needs to be considered. In  
209 addition, the function superficial muscles, with longer fast-glycolytic fibres create a larger range of  
210 movement over multiple intervertebral joints (Schilling 2011) which may be visually observed as  
211 atrophied, should be addressed. Exercises that recruit postural muscle fibres include the form of  
212 dynamic mobilisation exercises evaluated by Stubbs *et al* (2011). These are low intensity isotonic and  
213 isometric muscle contraction based range of movement exercises performed with the horse  
214 stationary. There has been no evaluation of specific exercises or neck positions during gait but in  
215 theory increasing intensity, in terms of body weight forces during movement, could promote further  
216 adaptive muscular changes.

217 If exercises are to be successful, neuromotor control, which refers to the quality and optimal function  
218 of the muscle and associated afferent and efferent neural connections, need to be considered.  
219 Optimal neuromotor control requires the processing of the proprioceptive input and subsequent  
220 output that effects timing of muscle recruitment and therefore relates to the ability to maintain joints  
221 in their appropriate position through their range of motion during locomotion and other perturbations  
222 (McGowan and Hyytiäinen 2017). With the neck acting as a cantilever beam at the front of the body  
223 (Gellman and Bertrum 2002), the requirement for co-ordinated movement and stability would appear  
224 critical to normal function of the region. In practice this means that the selection of therapeutic  
225 exercises should be chosen to represent functional movements and those that will target activation  
226 of the desired set of muscles. Dynamic mobilisation exercises, in the form of baited 'carrot' stretches,  
227 are often selected for this purpose (figure 2). The cervical intervertebral angles have been described  
228 by Clayton *et al.* (2010 and 2012) and the effect on *m. multifidus* muscle cross-sectional area, in the  
229 thoracolumbar region, by Stubbs *et al.* (2011) and de Oliveira *et al.* (2015)







230

231 Figure 2: Dynamic mobilisation exercises: A – chin to knee; B – chin between fetlocks; C – chin to  
 232 girth and D – chin to stifle. The horse is motivated, by using food bait, to move through a range of  
 233 motion that results in cervical and thoracolumbar flexion (Pictures A & B) and lateral flexion  
 234 (Pictures C & D).

235

236

237 Activation of the cervical musculature with the aim of hypertrophy and increased symmetry can be  
 238 achieved by baited exercises to take the spine through ranges of flexion, extension, rotation and  
 239 lateral flexion. Whilst evidenced to increase size and symmetry of *m. multifidus* in the thoracolumbar  
 240 region (Stubbs et al. 2011), the dynamic mobilisation exercises used encourage the horse to follow a  
 241 food reward to different positions, with the effect of a significant change of position of the joints in  
 242 the cervical spine. In the study by Stubbs et al. (2011) the exercises were repeated five days a week  
 243 for 12 weeks and each end of range posture was held for five seconds. This requires both concentric  
 244 and isometric contractions of the agonist muscles, eccentric contraction of the agonist and a likely  
 245 combination with the deep stability muscles. Following the principles of training (Castejon-Riber et al.  
 246 2017), progressive loading to stimulate adaption would result in development of the cervical  
 247 musculature. However, it should be remembered that if there is pain from an underlying osseous  
 248 condition there may be arthrogenic inhibition of the muscle function (Hopkins and Ingersoll 2000)  
 249 which will limit the effectiveness of therapeutic exercises until the pain is addressed.

250 Electrotherapy

251 In addition to manual therapy and exercise prescription, electrotherapy devices could be used as a  
 252 passive adjunct within a treatment paradigm. To the authors knowledge there is no research for  
 253 application of devices such as laser, therapeutic ultrasound and neuromuscular electrical stimulation  
 254 (NMES) specifically for the cervical region. Translation from application in other body areas and from  
 255 human studies would support the use of laser for pain relief (Chow et al 2009) although there is  
 256 suggestion that the presence of hair may affect comparable penetration depths so treatment dose  
 257 should be adapted. Therapeutic ultrasound would be more appropriate for high protein content  
 258 connective tissues, such as ligament and tendons, and therefore would be less suitable for treatment  
 259 in the neck region than injuries in the distal limb for example (Watson, 2008).

260 A good choice of adjunct would be NMES and small battery operated, portable devices are practical  
 261 to use in clinical practice. NMES can be used to facilitate rhythmical muscle contraction in the neck  
 262 muscles whilst may assist in restoration of normal activity, although to date there are no studies  
 263 discussing this approach. However, a reduction of pain and muscle tone has been shown in the

264 thoracolumbar region (Schils and Turner, 2014) and in practice the use of low frequency (less than  
265 10Hz) NMES generates a contraction in the region of muscle underlying the electrodes. If the NMES  
266 has induced pain relief, which has been reported in humans for both transcutaneous nerve stimulation  
267 and H-wave therapy in the short term (McDowell et al, 1999) this would provide a timeframe in which  
268 to apply other elements of the treatment approach. The stimulated local muscle contraction could be  
269 followed with active movement, using voluntarily recruited musculature, to work towards restoration  
270 of full range of movement.

#### 271 Advice and Education

272 Within the scope of physiotherapy is the delivery of advice to support the patient in their recovery  
273 and return to optimal function. This applies as much to the horse owner and rider, as to a human  
274 patient, despite the horse undergoing treatment in this case. The key points are to establish if there  
275 are any causative elements of the horse's daily activity or training that may be related to the presence  
276 of neck pain. In one recent case seen by the author, the addition of a hay feeder situated under a  
277 corner manger, required the horse to repetitively rotate his upper cervical spine during extension to  
278 reach the forage, inducing acute muscular pain. A further scenario involved a change of training  
279 intensity prior to a competition, which created the postural effect of increasing lower cervical  
280 extension and upper cervical flexion, aggravated the pre-existing facet OA and resulted in mild  
281 neurological signs and cervical muscle pain. Identification of risk factors and education on basic  
282 anatomy and function will aid prevention of onset and management of on-going neck pain.

#### 283 Conclusion

284 The recent increase in publications of veterinary studies into neck pain and pathology would suggest  
285 an increased recognition of dysfunction of this region as a cause of performance loss in horses.  
286 Veterinary medical intervention should be supported by physiotherapy management to aid pain relief  
287 and increase muscle size. Manual therapy and therapeutic exercises should be considered as useful  
288 adjuncts to assist return to function and full performance.

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#### 290 References

291 Alvarez CG, L'ami JJ, Moffatt D, Back W and Van Weeren PR. 2008. Effect of chiropractic manipulations  
292 on the kinematics of back and limbs in horses with clinically diagnosed back problems. *Equine  
293 Veterinary Journal*, 40(2):153-159.

294 Bishop MD, Torres-Cueco R, Gay CW, Lluch-Girbés E, Beneciuk JM and Bialosky JE. 2015. What effect  
295 can manual therapy have on a patient's pain experience?. *Pain Management*. 5(6):455-464.

296 Castejon-Riber C, Riber C, Rubio MD, Agüera E and Muñoz A. 2017. Objectives, principles, and methods  
297 of strength training for horses. *Journal of Equine Veterinary Science*. 56, pp.93-103.

298 Chartered Society of Physiotherapy (CSP) (2020) What is Physiotherapy? Available from:  
299 <https://www.csp.org.uk/careers-jobs/what-physiotherapy>

300 Chow RT, Johnson MI, Lopes-Martins RA and Bjordal JM. 2009. Efficacy of low-level laser therapy in  
301 the management of neck pain: a systematic review and meta-analysis of randomised placebo or active-  
302 treatment controlled trials. *The Lancet*, 374(9705), pp.1897-1908.

303 Clayton HM, Kaiser LJ, Lavagnino M and Stubbs NC. 2010. Dynamic mobilisations in cervical flexion:  
304 Effects on intervertebral angulations. *Equine Veterinary Journal*. 42(s38):688-694.



305 Clayton HM, Kaiser LJ, Lavagnino M and Stubbs NC. 2012. Evaluation of intersegmental vertebral  
306 motion during performance of dynamic mobilization exercises in cervical lateral bending in horses.  
307 American Journal of Veterinary Research. 73(8):1153-1159.

308 Cook J. and Docking S. 2015 Rehabilitation will increase the 'capacity' of your... insert musculoskeletal  
309 tissue here...." Defining 'tissue capacity': a core concept for clinicians. British Journal of Sports  
310 Medicine. pp. 1484-1485.

311 de Oliveira K, Soutello RV, da Fonseca R, Costa C, Paulo RDL, Fachioli DF and Clayton HM. 2015.  
312 Gymnastic Training and Dynamic Mobilization Exercises Improve Stride Quality and Increase Epaxial  
313 Muscle Size in Therapy Horses. Journal of Equine Veterinary Science. 35(11):888-893.

314 Down SS. and Henson FMD. 2009. Radiographic retrospective study of the caudal cervical articular  
315 process joints in the horse. Equine Veterinary Journal. 41(6):518-524.

316 Dyson SJ. 2011. Lesions of the equine neck resulting in lameness or poor performance. Veterinary  
317 Clinics: Equine Practice. 27(3):417-437.

318 Dyson S, Berger J. Ellis AD. and Mullard J. 2018. Development of an ethogram for a pain scoring system  
319 in ridden horses and its application to determine the presence of musculoskeletal pain. Journal of  
320 Veterinary Behavior, 23:47-57.

321 Fernández-de-las-Peñas C. Albert-Sanchís JC, Buil, M. et al. 2008. Cross-sectional area of cervical  
322 multifidus muscle in females with chronic bilateral neck pain compared to controls. Journal of  
323 Orthopaedic and Sports Physical Therapy, 38:175-180.

324 Gellman KS. and Bertram JEA. 2002. The equine nuchal ligament 2: passive dynamic energy exchange  
325 in locomotion. Veterinary and Comparative Orthopaedics and Traumatology. 15(01):07-14.

326 Gleerup KB. Forkman B. Lindegaard C. and Andersen PH. 2015. An equine pain face. Veterinary  
327 Anaesthesia and Analgesia. 42(1):103-114.

328 Haussler KK. 2009. Review of manual therapy techniques in equine practice. Journal of Equine  
329 Veterinary Science, 29(12), pp.849-869.

330 Haussler KK. and Erb HN. 2006. Mechanical nociceptive thresholds in the axial skeleton of  
331 horses. Equine Veterinary Journal, 38(1), pp.70-75.

332 Haussler KK. Martin CE. and Hill AE. 2010. Efficacy of spinal manipulation and mobilisation on trunk  
333 flexibility and stiffness in horses: a randomised clinical trial. Equine Veterinary Journal. 42:695-702.

334 Haussler KK. Pool RR. Clayton HM. 2020. Characterization of bony changes localized to the cervical  
335 articular processes in a mixed population of horses. PLoS ONE 14(9).

336 Hill C. and Crook T. 2010. The relationship between massage to the equine caudal hindlimb muscles  
337 and hindlimb protraction. Equine Veterinary Journal. 42:683-687.

338 Hopkins JT. and Ingersoll CD. 2000. Arthrogenic muscle inhibition: a limiting factor in joint  
339 rehabilitation. Journal of Sport Rehabilitation, 9(2), pp.135-159.

340 Hughes KJ. Laidlaw EH. Reed SM. Keen J. Abbott JB. Trevail T. Hammond G. Parkin TDH. and Love S.  
341 2014. Repeatability and intra-and inter-observer agreement of cervical vertebral sagittal diameter  
342 ratios in horses with neurological disease. Journal of Veterinary Internal Medicine. 28(6):1860-1870.

343 Javanshir K. Mohseni-Bandpei MA. Rezasoltani A. et al. 2011 Ultrasonography of longus colli muscle:  
344 A reliability study on healthy patients and patients with chronic neck pain. Journal of Bodywork and  
345 Movement Therapies. 15(1):50-56.

346 Koenig JB. Westlund A. Nykamp S. Kenney DG. Melville L. Cribb N. and Oberbichler D. 2020. Case-  
347 Control Comparison of Cervical Spine Radiographs From Horses With a Clinical Diagnosis of Cervical  
348 Facet Disease With Normal Horses. *Journal of Equine Veterinary Science*. 92:103176.

349 Lindgren CM. Wright L. Kristoffersen M. and Puchalski SM. 2020. Computed tomography and  
350 myelography of the equine cervical spine: 180 cases (2013–2018) *Equine Vet. Educ.* Version of record  
351 on line 16 July 2020.

352 May-Davis S. 2014. The occurrence of a congenital malformation in the sixth and seventh cervical  
353 vertebrae predominantly observed in thoroughbred horses. *Journal of Equine Veterinary  
354 Science*. 34(11-12):1313-1317.

355 May-Davis S. Brown W. and Vermeulen Z. 2018. The disappearing lamellae: implications of New  
356 findings in the family equidae suggest the loss of nuchal ligament lamellae on C6 and C7 occurred after  
357 domestication. *Journal of Equine Veterinary Science*. 68:108-114.

358 McDowell BC, McCormack K, Walsh DM, Baxter DG. and Allen JM. 1999. Comparative analgesic  
359 effects of H-wave therapy and transcutaneous electrical nerve stimulation on pain threshold in  
360 humans. *Archives of physical medicine and rehabilitation*, 80(9), pp.1001-1004.

361 McGowan C., Stubbs N. and Jull G. 2007. Equine physiotherapy: a comparative view of the science  
362 underlying the profession. *Equine Veterinary Journal*. 39(1), pp 90-4.

363 McGowan CM. and Hyytiäinen HK. 2017. Muscular and neuromotor control and learning in the athletic  
364 horse. *Comparative Exercise Physiology*. 13(3):185-194.

365 Merrifield-Jones M. Tabor G. and Williams J. 2019. Inter-and Intra-Rater Reliability of Soft Tissue  
366 Palpation Scoring in the Equine Thoracic Epaxial Region. *Journal of Equine Veterinary  
367 Science*. 83:102812.

368 Nout YS. and Reed SM. 2003. Cervical vertebral stenotic myelopathy. *Equine Veterinary  
369 Education*, 15(4), pp.212-223.

370 Rhodin M. Álvarez CG. Byström A. Johnston C. Van Weeren PR. Roepstorff L. and Weishaupt MA.  
371 2009. The effect of different head and neck positions on the caudal back and hindlimb kinematics in the  
372 elite dressage horse at trot. *Equine Veterinary Journal*, 41(3), pp.274-279.

373 Rombach N. 2013. The structural basis of equine neck pain. Michigan State University.

374 Rossignol R. Brandenberger O. Mespoulhes-Riviere. 2016. Internal fixation of cervical fractures in  
375 three horses. *Vet. Surg.* 45 104-109

376 Ryan T. and Smith, R.K.W., 2007. An investigation into the depth of penetration of low level laser  
377 therapy through the equine tendon in vivo. *Irish Veterinary Journal*, 60(5), p.295.

378 Schilling N. 2011. Evolution of the axial system in craniates: morphology and function of the  
379 perivertebral musculature. *Frontiers in Zoology*. 8(1):4.

380 Schils SJ. and Turner TA. 2014. Functional Electrical Stimulation for equine epaxial muscle spasms:  
381 retrospective study of 241 clinical cases. *Comparative Exercise Physiology*, 10(2), pp.89-97.

382 Sleutjens, J., Cooley, A.J., Sampson, S.N., Wijnberg, I.D., Back, W., van der Kolk, J.H. and Swiderski, C.E.  
383 (2014) The equine cervical spine: comparing MRI and contrast-enhanced CT images with anatomic  
384 slices in the sagittal, dorsal, and transverse plane *Veterinary Quarterly* **34** 74-84.

385 Stubbs NC. Kaiser LJ. Hauptman J. and Clayton HM. 2011. Dynamic mobilisation exercises increase  
386 cross sectional area of musculus multifidus. *Equine Veterinary Journal*. 43(5):522-529.

- 387 Sullivan KA. Hill AE. and Haussler KK. 2008. The effects of chiropractic, massage and phenylbutazone  
388 on spinal mechanical nociceptive thresholds in horses without clinical signs. *Equine Veterinary*  
389 *Journal*. 40(1):14-20.
- 390 Tabor G. 2020a. An Investigation of Equine Musculoskeletal Conditions within Equine  
391 Physiotherapists' Caseloads. UK Equine Student Conference.
- 392 Tabor G. 2020b. Routine equine physiotherapy. *Equine Vet Educ*, 32: 349-351.
- 393 Veraa S. de Graaf K. Wijnberg ID. Back W. Vernooij H. Nielen M. and Belt, AJM. 2020.. Caudal cervical  
394 vertebral morphological variation is not associated with clinical signs in Warmblood horses. *Equine*  
395 *Veterinary Journal*, 52(2), pp.219-224.
- 396 Voigt A. Saulez MN. and Donnellan CM. 2009. Nuchal crest avulsion fracture in 2 horses: a cause of  
397 headshaking. *Journal of the South African Veterinary Association*. 80(2):111-113.
- 398 Watson T. 2008. Ultrasound in contemporary physiotherapy *practice*. *Ultrasonics*, 48(4), pp.321-329.
- 399 Weerapong P. Hume PA. and Kolt GS. 2005. The mechanisms of massage and effects on performance,  
400 muscle recovery and injury prevention. *Sports Medicine*. 35(3):235-256.
- 401 Zsoldos RR. and Licka TF. 2015. The equine neck and its function during movement and  
402 locomotion. *Zoology*. 118(5):364-376.