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Running header: Effects of massage on gait in riding school horses

Abstract
Musculoskeletal injuries have been reported to be the main contributor to the interruption or dismissal of a horse's athletic career. The muscles are responsible for the production of forces involved in movement, yet the muscles are often overlooked with regards to pre/rehabilitation. The use of massage therapy as part of a training programme is becoming increasingly popular. The beneficial effects of massage have been widely researched, though much of the research is on the immediate effects, and consistency between studies is lacking. This study was a preliminary investigation in to the effects of a short-term massage programme on the gait parameters of riding school horses. Methods: 15 clinically sound riding school horses of different breed, age and height were used in a controlled, blind study. The horses were divided in to three groups of five ensuring a mixture of height, breed and age. Group massage has received 10minute massage each side on the proximal hindlimb, once a week for three weeks. Group sham has received 10minute groom each side on the proximal hindlimb, once a week for three weeks; and Group control has received no treatment. Gait analysis was conducted on days 1 and 28. Results: In walk, a significant improvement in stride length symmetry index (SI) ($p = 0.043$) and protraction SI ($p=0.0043$) was found for group massage, with hock flexion SI significantly better for group massage day 28 ($p = 0.03$). At trot and canter, hock flexion SI was improved in group massage ($p=0.003$ and $p=0.024$, respectively). Conclusions: A short-term massage programme to the proximal hindlimb improved gait symmetry, particularly hock flexion SI, within riding school horses. An appropriate dosage level for particular results needs to be determined in order to effectively utilise massage within a training programme. Further studies analysing kinetic parameters alongside kinematic parameters will enable further conclusions to be drawn.

Keywords: biomechanics, performance, physiotherapy, rehabilitation, therapy
Conflicts of Interest: None.

Introduction

Musculoskeletal injuries have been reported to be the main contributor to the end or disruption of a horse's athletic career (Weishaupt *et al.,* 2001) and the most common cause of poor performance in horses are subclinical disorders of the locomotor system (Morris and Seeherman, 1991). Reports have found lameness results in a $1 billion annual loss to the equine owning public in America (Pfau *et al.,* 2007), and the prevalence of musculoskeletal injuries within 3 racing yards in Newmarket was 23-26% per year (Ramzan and Palmar, 2011); which causes large wastage problems and money losses.

Some horses fail to reach their expected potential while others reach levels never deemed possible; but one common factor between them, is that their musculoskeletal system is equal to approximately 60% of their total body weight (Booth 2009), and when this system is responsible for movement, it is imperative to maintain full function to ensure maximum potential is reached, whilst limiting the risk of injury (Valberg, 2018). Dressage, Show-jumping, Eventing and Racing are four of the biggest equine sports in the World, with Endurance also growing in popularity. Dressage requires the horse to balance itself and is an evaluation of controlled power and balance; this causes a lot of gradual damage due to excessive movements resulting in inappropriate joint and limb angulations, poor management conditions and inappropriate utilisation of the immature skeletal system, and conformational genetics causing weakness and predisposition to injury (Dyson, 2000; Murray *et al.* 2010). Showjumpers experience huge forces on their tendons and ligaments which in turn pull on joints and muscles causing instability and damage (Dyson, 2000; Thorpe *et al.*2010). Eventers undertake the dressage and show jumping phases with the added cross-country element. All three phases require different skills, meaning they are often not always suitably prepared for all 3 three phases. The physical demands of the cross-country element add fatigue into the equation; therefore, if a horse is not in peak condition, then muscular damage may onset and repetitive injuries can occur (Stashak, 1987).

Signs of muscle damage and pain are not always evident, yet subclinical signs such as an increase in creatine kinase (CK) in the blood indicating muscle damage causes leakage of this protein (Goer, 2000). 15% of horses investigated for poor performance showed signs of muscle injury in response to a standardised exercise test (Martin *et al.* 2000); therefore, protection of the muscles is vital in ensuring maximum potential is reached and maintained. With this information being known, competition legal methods of prevention and rehabilitation are of great importance to ensure welfare is maintained, with massage being a highly popular modality (Thirkell and Hyland 2019). In modern competition the difference between winning and losing can be as little as a few milliseconds or points of a percentage; therefore, methods of preventing injury by improving performance are of particular interest (Guest and Cunliffe, 2014).

Massage has been found to help alleviate stress short term by reducing heart rate and improving behavioural indicators (McBride *et al.,* 2004) which could be utilised prior to events, especially with horses known to become stressed when competing. Salter *et al.* (2011) found massage increased cutaneous temperature, which as a preliminary finding suggests a cardiovascular response is occurring, which could be utilised as a method for warming up horses prior to exercise, and suggests an increased ability to recover from exercise via improved waste removal. Hill and Crook (2010) found massage increased passive and active hind limb protraction compared to a control group, supporting the findings of Wilson (2002), the first study to analyse the effect of massage on range of motion in horses. However, these studies looked at the initial effects of massage, and no study has been performed on the effects of a short term programme and on the optimal dosage in a period of time. Rose *et al*. (2009) established a 3 day stretching programme increased range of motion in the shoulder, stifle and hock, but noted the 6 day stretch routine significantly reduced ROM compared to the 3 day and non-stretch groups; suggesting stretching daily may be too intensive and cause damage to the muscle (Rose *et al.,* 2009; Smith *et al.,* 1994), which alludes to the importance of application protocols for massage also.

Research that has been performed is also contradictory due to a lack of protocol understanding. White *et al*. (2014) found massage in riding school horses decreased pressure thresholds at stress points, particularly on the left side immediately after massage which contradicts Sullivan *et al*. (2008) who found massage increased spinal mechanical nociceptive thresholds. The conclusions to these findings are unclear; however, they could be suggestive of the removal of compensatory mechanisms having negative effects, particularly due to the nature of their ridden work and the continued use of the left side when handling horses; or may be due to the difference in timings of massage and MNT measurements. Therefore, further research is

imperative and emphasise the need for appropriate massage procedures to be determined (Thirkell and Hyland, 2019).
Research results are varied and inconsistent but show promise. The behavioural responses to massage accompanied with improvements in ROM and pain thresholds mean the effects of massage on performance are of further interest.. Most of the research conducted is on the initial effects of massage and researching the effects of a short-term programme are of benefit to decipher the true effects of massage in terms of performance. The purpose of this study was to develop an improved understanding of the role of regular massage sessions in horses with no known health problems undergoing regular repetitive work by assessing both kinematic gait parameters and perceived improvement which is vital in terms of competitive success.
The aim of the study was to investigate the impact of a short-term massage programme, sham treatment programme and a control, on gait parameter variables of riding school horses.

Materials and Methods

Ethical Approval

This study was approved by the Notting Trent University ethics committee. Informed, written consent was obtained prior to participation in the study. At the time of the study, all horses and riders were free from any injuries and riders or owners could withdraw their participation from the study at any point.

Animals

Fifteen clinically sound riding school horses at the same institution, of different breed, age and height were used in a controlled, blinded study. The horses continued their usual management routines throughout the study. The horses underwent medium work and received similar management routines. No horses in the study received any other forms of manipulative therapy during the study. Sample utilised was a convenience sample based on horses available at the university during the period of study. The sample size (minimum 5/group and maximum 7/group) was determined using the resource equation approach as described by Arifin and Zahiruddin (2017).
This study was a non-randomised controlled trial with matched pairs. The 15 horses were divided in to three matched groups based on height breed and age. Group massage (height – 1.6±0.08m, age – 13.2+5.9years) received a 20 minute massage (10 minutes each side) on the proximal hind limb, once a week on the same day for three weeks, on weeks 1, 2 and 3. Group sham (height – 1.6±0.1m, age – 13.6±5.2years) received a 20 minute grooming in frequency and the same areas massaged on group massage; and Group control (height – 1.6±0.08m age – 12.6±5.3years) received no treatment.

Riders:

Two riders were utilised of similar weight (10-12stone), and height. Both riders were considered competent at stage 3 BHS level. Riders rode the same horses on D1 and D28, with equal horse division between riders. Both riders were blinded to the study.

Massage Technique

The massage was performed by a qualified and insured equine sports massge therapist (C.M.) Each horse in group massage received 20 minutes of massage, 10 minutes either side. The massage consisted of two minutes of effleurage followed by two minutes of cross fibre massage, two minutes of tapotement (cupping), two minutes of cross fibre massage and finished with two minutes of effleurage, all with different physiological and biomechanical effects found to influence musculoskeletal health and performance (Weerapong *et al.* 2005). The massage was conducted on the *gluteus superficialis, gluteus medius, tensor facia latae*, *semitendinosus, biceps femoris* and *gastrocnemius* muscles, i.e. the proximal muscles of the equine hindlimb. Effleurage is defined as a technique in massage in which long, light or firm strokes are used following the natural flow of circulation. Cross friction is applied transversely over the muscle fibres using the fingertips. Local compressions separate the fibres and break up any adhesions. Tapotement is a double-handed technique, cupping was used where loosely cupped palms trap air between the palms and the horse Tapotement must be performed in a rhythmic motion; as one hand makes contact with the subject, the other is lifted (Bromiley, 2007). The horse's rugs were removed 5 minutes prior to the beginning of treatment and a thermal image was taken after the 5 minute period, starting with the left side, and 1 minute post massage.

Sham (Grooming) Treatment

During the 20 minute sham treatment (group sham), horses stood in the same environment with the therapist grooming the muscles massaged in the massage procedure for the same amount of time, using a body brush.

Gait Analysis

Video gait analysis was conducted on weeks 0 (D1) and 4 (D28) using a Canon IXUS 990s digital camera, at 120Hz, grooming was not performed prior to gait analysis. Horses underwent a standard five-minute warm-up before being ridden down a set lane of 3-5 strides (Schamhardt, 1996) three times in each gait (walk, trot and canter) on each rein; with the camera 9m back, perpendicular to the lane in the centre. Horses were ridden in their usual flatwork tack and riders were briefed to ride each horse equally asking for their natural rhythm with minimal interference. Horses did not undergo any other forms of exercise on study days, but remained in their usual routine for the rest of the days during the trial.

Video Analysis

Video analysis was performed using the sports analysis programme Kinovea (v. 0.8.15, Kinovea, Bordeaux, France). The outcomes measured for gait parameters were: stride length, maximum hock flexion and hind limb protraction. The stride most central to the frame was analysed. Skin markers had been used during data collection for use during analysis. Markers were placed on the greater trochanter, lateral patella, tuber calcanei and metatarsophalangeal joint at the experience of the therapist. Stride length was measured using the inside hind limb from when the entire hoof was placed on the floor to the next time this placement occurred; measuring from point of toe to point of toe. Hock angle was measured internally from patella to tuber calcanei to fetlock at maximum flexion. Protraction was measured from point of toe during protraction to a vertical plumline from the coxofemoral joint. This was performed for each horse, both days (D1 and D28), on walk, sitting trot and canter (lead hindlimb) on both reins. . For each gait (walk, trot and canter), six strides were analysed (three strides on each rein). Velocity for each gait and rein was tested for significant differences between D1 and D28 to ensure there were no variance in speed, allowing direct comparisons between timepoints.

Symmetry Index (SI)

Data for each horse, gait parameter, treatment group and day was collated and grouped in to three tables, one for each gait (walk, trot and canter), and a symmetry index for each rein was calculated for each gait parameter. Contralateral symmetry was calculated by dividing the lower value by the higher value creating a value less than 1.0 (Clayton *et al.,* 2002). A value of 1.0 indicates perfect symmetry.

Statistical Analysis

Statistical analysis was run using the SPSS (v. 28, IBM). Outliers were maintained due to nature of data and biological variability. Statistical significance was set at <0.05.

Normality of data was tested with Shapiro-Wilk tests and boxplot inspection. The following statistical tests were performed:

(1) Speed at the different timepoints (D1 and D28) was tested using a Wilcoxon test. Speed between groups was tested at the two timepoints using Kruskal-Wallis tests.

(2) A Wilcoxon test was performed for non-parametric data, whereas a paired t-test was used for parametric; in order to test if significant differences could be individuated between D1 and D28 of each symmetry index for each treatment group on all gaits tested.
(3) A one-way ANOVA was used to compare the outcomes of different groups, at D1 and D28, when data was of parametric nature; Kruskal-Wallis test was performed on the non-parametric data, to compare different treatment groups at D1 and D28. For both tests a Bonferroni correction was applied on the post-hoc tests.

Results

One horse was removed from the study following the first week due to an unrelated injury. Speed for walk, trot and canter was tested for significant differences between D1 and D28 for each rein to ensure validity of results. No significant differences were found (p>0.05) allowing an unbiased comparison between the two timepoints. Furthermore, although not strictily controlled, within each horse the speed variation between D1 and D28 was below 0.2m/s at each gait. There was no significant difference in speed between groups at D1 and at D28 (p>0.05).
Data reported is mean±standard deviation, unless stated otherwise.

Stride length SI

At walk, stride length symmetry has shown no statistically significant differences between groups neither at D1 (F(2,11)=2.676, p=0.113) or at D28 (Z=3.243, p=0.198). However, when analysed within treatment group, at walk, the group massage had a statistically significant increase from D1 (Median=0.94) to D28 (Median=0.99) (Z=-2023, p=0.043) (Figure 1). The other groups have not had statistically significant differences between D1 and D28, at walk (p>0.05). No further significant differences were observed in stride length SI at trot and canter (p>0.05).

Hock flexion SI

Hock flexion SI at walk had no statistically significant differences at D1 (F(2,11)=5.869, p=0.320), but there were significant differences between groups at D28 (Z=7.586, p=0.023). Group massage (Median=0.99) has shown a significant higher hock flexion SI than group control (Median=0.96) (p=0.03) at D28 (Figure 2.i). When comparing within each individual treatment group, there was no differences in hock flexion SI between D1 and D28 (p>0.05) at walk.
Likewise, on trot (F(2,11)=9.727, p=0.04) and canter ($x^2(2)$=7.060, p=0.03), at D28, there was a statistically significant difference between groups. On trot, hock flexion SI was higher on group massage (0.986±0.01) than group control (0.93±0.02) (p=0.003) (Figure 2.ii). And on canter, the same trend was observed, hock flexion SI was higher on group massage (0.98±0.02) than group control (0.94±0.02) (p=0.024) (Figure 2.iii).
Furthermore, on canter, massage has elicited statistically significant differences between D1 and D28 for group massage. Hock flexion SI has increased from D1 (0.94±0.033) to D28 (0.98±0.023) (Z=2.023, p=0.043) (Figure 2.iii).

Hindlimb Protraction SI

The massage treatment has shown an improved hindlimb protraction SI at walk at D28 (0.96±0.028) when compared with D1 (0.89±0.037) (Z=-2.023, p=0.043). The other groups have not shown significant changes in protraction SI at walk from D1 to D28 (p<0.05). At D1, there was no significant differences between groups when protraction SI was analysed at walk (F(2,11)=0.418, p=0.669), but at D28 there has been statistically significant differences detected between groups ($F(2,11)= 5.869$, $p=0.018$. At post-hoc tests for protraction SI at walk, the massage has elicited a better protraction SI at walk than no treatment ($p=0.03$) (Figure 3). No further significant differences were observed in hindlimb protraction SI at trot and canter ($p>0.05$).

Discussion

A short-term massage programme has shown significant improvement in hock flexion SI at all gaits. Furthermore, stride length and hindlimb protraction SIs have shown an improvement at walk, after the massage programme. The results have shown that a short-term massage programme can improve hindlimb kinematics symmetry.

In this study, all the kinematic variables showed positive improvements for group massage in all three gaits, although some were not statistically significant. Whereas groups sham and control showed varied changes between D1 and D28 for each kinematic variable for all three gaits, most likely due to the result of intra-subject variability (Lynch *et al.,* 2005; Pourcelot *et al.,* 1997).

Walk is the only gait where elastic recoil within the tendons is not utilised to improve gait function. Almost the entirety of movement is generated from the hindlimb retractors, suggesting the significant increase in protraction and stride length, observed for group massage, is due to the massage performed on the muscles responsible for extension of the hip such as the *gluteus medius*, *semitendinosus,* and *biceps femoris* (Crook *et al.,* 2010; Tabor and Williams, 2018).

In canter, due to the asymmetric nature of the gait, all four limbs play different roles in controlling the movement, with flexion and extension of the lumbosacral region influencing motion (Johnson and Moore-Colyer, 2009; Tokuriki and Aioki, 1995); nonetheless massage on the muscles of the proximal hind limbs was sufficient to significantly improve hock flexion SI at D28. Canter utilises tendon recoil for energy for propulsion, and the trailing limb is responsible for the majority of propulsion with the leading limb responsible for transferring this into the forward motion (Back, 2001); the significant improvement in hock flexion SI accompanied by improvements, although not significant, in protraction SI and stride length SI suggest massage improved the hind limb kinematics within the canter; however, massage of forelimbs may show more significant results.

The trot has also shown improvements in hock flexion SI, however all kinematic variables did improve for group massage between D1 and D28, with results suggesting massage was influencing kinematics of the hind limb during trot. It has been found movement of the hind limbs during trot is mainly controlled by elastic recoil within the tendons (Back, 2001); suggesting massage to the proximal hind limb has improved hock flexion SI as two of the muscles targeted by the massage programme have some action on hock motion. The massage may not have been sufficient to produce significant improvements in stride length and protraction SI, maybe because the muscles targeted have a more evident action in retracting the hindlimb than protraction function. Therefore, we can infer that the effects of massage of the entire hind limb on hind limb kinematics warrants investigation. Back *et al.* (1996) established that kinematic parameters for the walk were reflective of kinematic parameters within the trot, indicating the significant improvements in walk found in this study will lead to significant improvements within the trot. This highlights the importance of assessing all three gaits and not just analysing the trot; and the need for further studies to determine the length of programme needed before certain changes within the gait occur, paying particular attention to sports horses within a training programme.

As any experimental study, the present one has faced some limitations. These factors included the use of a 2-D imaging system, the small sample size and the lack of strict control of speed, but the authors attempted to reduce the effects of these factors on the data so that results would be representative of characteristics of the sagittal motion of horses limbs. We attempted to minimize the effects of any variable by using the same person to place markers on all of the horses, set up the video camera for each horse during each recording session, and manually analyse all the videos. In addition, 6 strides for each horse at each gait were analysed; this was intended to minimize variability attributable to the data collection system. Furthermore, speed was tested to ensure there were no significant different between groups or between timepoints. The findings of this study in a small sample of horses are encouraging to support massage therapy. However, further studies are needed to determine appropriate protocols for a range of uses, such as “pre-exercise warm up”, “cool down”, as-well-as branching further in to rehabilitation protocols for different sporting injuries. Appropriate protocols however will depend on the desired response, such as cardiovascular increase in the muscle as the primary aim, to reducing scar tissue adhesions and improving muscle extensibility as the primary aim. Additionally, whilst practitioner education remains wholly unregulated, protocol determination will remain difficult to formulate in terms of maintaining massage speed, pressure, duration, and format; therefore, it is pertinent the industry continues to strive for regulation status alongside scientific protocol research.

Conclusions

It can be concluded that a short-term massage programme to the proximal hind limb consistently improved gait symmetry within riding school horses. Further studies analysing kinetic parameters alongside kinematic parameters will enable further changes within the gait to be determined and may help establish dosage rates and causes of gait improvement from massage. If massage to the proximal muscles of the hind limb can improve stride length, protraction and flexion in ‘normal subjects’, it may well have a beneficial place in training programmes to improve performance and prevent injury, and have rehabilitative uses.

References

Arifin WN, Zahiruddin WM. 2017. Sample Size Calculation in Animal Studies Using Resource Equation Approach. Malaysian Journal of Medical Sciences. 24(5):101-105. doi: 10.21315/mjms2017.24.5.11.

Back, W., 2001. Intra-Limb Co-Ordination. In: Back, W., Clayton H., 1st ed. Equine Locomotion. W.B. Saunders, London, UK

Back, W.M., Schamhardt, H.C., Barneveld, A., 1996. Are kinematics of the walk related to the locomotion of a Warmblood horse at the trot? Veterinary Quarterly 18: 79-84

Booth, R., 2009. An introduction to massage and stretching. Elementals Equine Therapies. Available at: http://media.wix.com/ugd/43e865_100fa815995c42ce8228231bdf3a503e.pdf

Clayton, H., Almeida, P.E., Brown, J., Lanovaz, J.L., Prades, M., Tessier, C., 2002. Double Blind Study of the Effects of an Oral Supplement Intended to Support Joint Health in Horses with Tarsal Degenerative Joint Disease. Proceedings of the Annual Convention of the AAEP 48: 314-317

Crook, T.C., Wilson, A., Hodson-Tole, E., 2010. The effect of treadmill speed and gradient on equine hindlimb muscle activity. Equine Veterinary Journal 42: https://doi.org/10.1111/j.2042-3306.2010.00222.x

Dyson, S., 2000. Lameness and Poor Performance in the Sports Horse: Dressage, Show Jumping and Horse Trails (Eventing). MEP Proceedings 22: 308-315

Goer, R., 2000. What Causes Poor Exercise Performance? Article: The Horse. Available at: http://www.thehorse.com/articles/10117/what-causes-poor-exercise-performance

Guest, J., Cunliffe, C., 2014. The Effects of Chiropractic Treatment on The Range of Motion of the Carpus and Tarsus of Horses. Equine Veterinary Journal 46: 40-41

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

Johnson, J.L., Moore-Colyer, M., 2009. The relationship between range of motion of lumbosacral flexion-extension and canter velocity of horses on a treadmill. Equine Veterinary Journal 41: https://doi.org/10.2746/042516409X397271

Lynch, J.A., Clayton, H.M., Mullineaux, D.R., 2005. The reliability of force platform data from trotting horses. Equine and Comparative Exercise Physiology 2: 129-132

Martin, B.B., Reef, V.B., Parente, E.J., Sage, A.D. 2000. Causes of poor performance of horses during training, racing, or showing: 348 cases (1992-1996). Journal of the American Veterinary Medical Association 216: 554-558

McBride, S.D., Hemmings, A., Robinson, K., 2004. A preliminary study on the effects of massage to reduce stress in the horse. Journal of Equine Veterinary Science 24: 76-81

Morris, E.A., Seeherman, H.J., 1991. Clinical Evaluation of Poor Performance in the Racehorse: The Results of 275 Evaluations. Equine Veterinary Journal 23: 169-174

Murray, R.C., Waltersm J.M., Snart, H., Dyson, S.J., Parkin, T.D.H., 2010. Identification of risk factors for lameness in dressage horses. The Veterinary Journal 184: https://doi.org/10.1016/j.tvjl.2009.03.020

Pfau, T., Robilliard, J.J., Weller, R., Jespers, K., Eliashar, E., Wilson, A.M., 2007. Assessment of Mild Hindlimb Lameness During Over-Ground Locomotion Using Linear Discriminant Analysis of Inertial Sensor Data. Equine Veterinary Journal 39: 407-413

Pourcelot, P., Degueurce, C., Audigie, F., Denoix, J.M., Geiger, D., 1997. Kinematic Analysis of the Locomotion Symmetry of Sound Horses at a Slow Trot. Equine Veterinary Journal 23: 93-96

Ramzan, P.H., Palmer, L., 2011. Musculoskeletal injuries in Thoroughbred racehorses: a study of three large training yards in Newmarket, UK (2005-2007). Veterinary Journal 187: 325-329

Rose, N.S., Northrop, A.J., Brigden, C.V., Martin, J.H., 2009. Effects of a stretching regime on stride length and range of motion in equine trot. The Veterinary Journal Special Issue: Equitation Science 181: 53-55

Salter, M.M., McCall, C.A., Pascoe, D.D., McElhenney, W.H., Pascoe, C., 2011. Effect of Equine Sports Massage Therapy on Cutaneous Temperature. Journal of Equine Veterinary Science 31: 322-323

Schamhardt, H.C., 1996. Quantitative analyses of equine locomotion. In: Back, W., Clayton H., 2nd ed. Equine Locomotion. W.B. Saunders, Oxford, UK

Smith, L.L., Keating, M.N., Holbert, D., Spratt, D.J., McCammon, M.R., Smith, S.S., Isreal, R.G., 1994. The effects of athletic massage on delayed onset muscle soreness, creatine kinase, and neutrophil count: a preliminary report. Journal of Orthopaedic Sports Physical Therapy 19: 93-9

Stashak, T.S., 1987. Adam's lameness in horses. 4th ed. Lea and Febiger, Philadelphia

Sullivan, K.A., Hill, A.E., Haussler, K.K., 2008. The effects of chiropractic, massage and phenylbutazone on spinal mechanical nociceptive thresholds in horses without clinical signs. Equine Veterinary Journal 40: 14-20

Tabor, G., Williams, J., 2018. Equine Rehabilitation: A Review of Trunk and Hind Limb Muscle Activity and Exercise Selection. Journal of Equine Veterinary Science. 60: https://doi.org/10.1016/j.jevs.2017.03.003

Thirkell, J., Hyland, R., 2019. A Survey Examining Attitudes Towards Equine Complementary Therapies for the Treatment of Musculoskeletal Injuries. Journal of Equine Veterinary Science. 59: https://doi.org/10.1016/j.jevs.2017.10.004

Thorpe, C.T., Clegg, P.D., and Birch, H.L., 2010. A review of tendon injury: Why is the equine superficial digital flexor tendon most at risk? Equine Veterinary Journal 42: https://doi.org/10.2746/042516409X480395

Tokuriki, M., Aoki, O., 1995. Electromyographic activity of the hindlimb muscles during the walk, trot and canter. Equine Veterinary Journal 18: 152-155

Valberg, S.J., 2018. Muscle Conditions Affecting Sport Horses. Veterinary Clinics of North America: Equine Practice, 34: https://doi.org/10.1016/j.cveq.2018.04.004

Weerapong, P., Hume, P.A., Kolt, G.S., 2005. The Mechanisms of Massage and Effects on Performance,mMuscle Recovery and Injury Prevention: Sports Medicine 35: https://doi.org/10.2165/00007256-200535030-00004

Weishaupt, M.A., Wiestner, T., Hogg, H.P., Jordan, P., Auer, J.A., Barrey, E., 2001. Assessment of Gait Irregularities in the Horse: Eye vs. Gait Analysis. Equine Veterinary Journal 33: 135-140

White, C., Bonnin, L., Hall, C., 2014. The use of pressure algometry to evaluate the immediate effect of sports massage in riding school horses. Conference Proceedings: 10th International Equitation Science Conference

Wilson J., 2002. The effects of sports massage on athletic performance and general function. Massage Therapy Journal. Available at: http://www.sportsmassageinc.com/EffectsOfSportsMassage.pdf

Figure legends

Figure 1. Stride length symmetry index (SI) at walk for the different treatments. Massage treatment (n=5); sham treatment (n=4); control (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the ‘x’ is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between D1 and D28 within groups ($p<0.05$). ** represent significant difference between groups ($p<0.05$).

Figure 2. Hock flexion symmetry index (SI) at walk (i), trot (ii) and canter (iii) for the different treatments. Massage treatment (n=5); sham treatment (n=4); control (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the ‘x’ is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between D1 and D28 within groups ($p<0.05$). ** represent significant difference between groups ($p<0.05$).

Figure 3. Hindlimb protraction symmetry index (SI) at walk for the different treatments. Massage treatment (n=5); sham treatment (n=4); control (n=5). The bottom and top of the box are the first and third quartiles, the band inside the box is the second quartile (the median), and the ‘x’ is the mean. The lines extending vertically from the boxes (whiskers) indicate the minimum and maximum of all of the data. * represents significant differences between D1 and D28 within groups ($p<0.05$). ** represent significant difference between groups ($p<0.05$).