The Use Of Treadmills Within The Rehabilitation Of Horses
Nankervis, Launder, Murray
The original publication is available at http://dx.doi.org/10.1016/j.jevs.2017.01.010

# THE USE OF TREADMILLS WITHIN THE REHABILITATION OF HORSES.

Kathryn J. Nankervis*, Elizabeth J. Launder[a] and Rachel C. Murray[b].

*Performance in Equestrian Sport Group, Hartpury University Centre, Hartpury, Glos. GL19 3BE, U.K; [a]Osteopathy for Horse and Rider, Llanerfyl, Welshpool, Powys, SY21 OEY, U.K.; [b]Centre for Equine Studies, Animal Health Trust, Kentford, Newmarket, Suffolk, CB8 7UU, UK.

*Corresponding author: kathryn.nankervis@hartpury.ac.uk

## Abstract

Treadmills and water treadmills are found in research centres, therapy centres and are becoming increasingly common in private competition yards, yet little evidence exists which informs their use for rehabilitation of injury. The control that they afford in terms of speed, intensity and duration of exercise is attractive, but guidance regarding any possible benefits and/or contraindications for treadmill exercise in any given scenario is limited. In this review the evidence pertaining to the physiology and biomechanics of treadmill exercise in horses is examined and combined with our experiences of using treadmills for rehabilitation over 15 years to offer some basic guidelines as to their use. Evidence is presented to support the use of a land treadmill in the rehabilitation of horses following various distal limb conditions and back pain. The effects of water treadmill exercise on limb and back kinematics are considered and suggestions made as to how to select the most appropriate water depth for various conditions. Successful rehabilitation depends as much on avoidance of unsuitable exercise as selection of beneficial exercise. In time, more evidence regarding the use of treadmills for specific conditions will accrue; but as horses commonly suffer from multiple conditions (e.g. hind limb lameness and back pain), it is likely that a rationale devised on a case by case basis will always be necessary, with regular monitoring of the gait pattern throughout rehabilitation.

Keywords: treadmill, rehabilitation, hydrotherapy, physiotherapy, lameness

## Highlights

- Land treadmill exercise has many benefits for rehabilitation.
- Compared to ridden work, treadmills offer controlled exercise with reduced load
- Back and limb kinematics are significantly altered during water treadmill exercise
- Vets should make recommendations for treadmill exercise on a case by case basis

## 1. Introduction

Treadmills and water treadmills are found in research centres, therapy centres and are becoming increasingly common in private competition yards, yet little evidence exists which informs their use for rehabilitation of injury. The control that they afford in terms of speed, intensity and duration of exercise is attractive, but guidance regarding any possible benefits and/or contraindications for treadmill exercise in any given scenario is limited. Within this review we shall examine the evidence pertaining to the physiology and biomechanics of treadmill exercise in horses and combine this with our experiences of using treadmills for rehabilitation over 15 years to offer some basic guidelines as to their use (see Table 1). Successful rehabilitation depends as much on avoidance of unsuitable exercise as selection of beneficial exercise. In time, more evidence regarding the use of treadmills for specific conditions will accrue; but as horses commonly suffer from multiple conditions (e.g. hind limb lameness and back pain), it is likely that a rationale devised on a case by case basis will always be necessary, and to develop this rationale requires a full understanding of the exercise being undertaken and its likely effects on limb loading, stride kinematics, posture and muscle development.

### 1.1 Type of treadmills available

For the purpose of this review a 'land/high-speed/dry' treadmill will be referred to as a land treadmill, as distinct from a 'water treadmill'. Land treadmills offer variable speed (often from 1.4 m/s to up to 16 m/s) and often a variable incline (0-10% or 6°). Fans are required even for low speed exercise on a land treadmill as heat loss due to convection and evaporation are reduced when a horse exercises in a closed air space.  Water treadmill speeds range from 0.1 m/s to 5.5 m/s and do not normally have the ability to incline. Water depth can be increased up to 1.50 m and whilst the literature reports use up to 80 % of wither height [1], most users do not work horses in much more than stifle depth water. The comfortable walking speed for a horse on a water treadmill is generally slower than walking overground or on a land treadmill.

### 1.2 Preparation of the horse.

Several studies have considered habituation to exercise on a land treadmill [2,3] and a water treadmill [4,5]. The vast majority of horses present no problems and quickly habituate to both types of exercise. Once habituated, horses show a high constancy (or low intra-horse variability) in stride variables [3]. The movement of the belt makes it difficult for an exuberant horse to buck or rear and so the horse is more constrained  than during in–hand walking or when on a horsewalker. In our experience protective boots are unnecessary for low speed work and are problematic in water, as they tend to slip or become loose. For water treadmill exercise the horse should be clean with the feet picked out and the tail wrapped up to minimise water contamination. Within our Centre, sedation is used for the first session of water treadmill exercise. A study comparing the heart rates of horses over the course of the first four water treadmill sessions showed that horses that were started without sedation exhibited higher peak heart rates (over the course of the first four sessions) than horses that were started with sedation for the first session only [4].

1.2.1 Risk associated with high-speed treadmill exercise.

In many centres a safety harness is used for canter and gallop exercise on a high speed treadmill and will immediately stop the belt in the event of a horse stumbling. For either low or high-speed exercise it should always be the handlers responsibility to ensure the horse maintains its position on the belt. Contrary to the popular misconception that land treadmill exercise is somehow more damaging to limbs than overground exercise, Franklin et al [6] found that the incidence of major injuries sustained whilst exercising on high-speed treadmill for the purpose of treadmill endoscopy is comparable with that reported during competition. This evidence, coupled with knowledge of rapid physiological habituation (i.e. after two exposures) [2] provides a certain reassurance as to the relative level of risk of this type of exercise and to its suitability for a wide range of horses.

**1.3 Aspects of land treadmill exercise related to rehabilitation**

1.3.1 Control.

One of the major benefits of land treadmill exercise over in-hand walking for the rehabilitation of distal soft tissue injury e.g. tendinopathy of the superficial digital flexor tendon (SDFT) is that the speed and the surface is controlled. The duration of walking is adjusted in response to changes in heat/swelling of the limb in the early stages of injury and the speed of walking is more easily standardised than in hand walking. As a result of increased standardisation of exercise, it is easier to ensure that the limb is progressively loaded using suitable small increments in duration and intensity. During in-hand walking, horses with a long stride length in particular are often restricted by the handler which leads to crookedness (usually left bend towards the handler on the left side of the horse) and/or loss of control. Exercising on a land treadmill reduces this problem to some extent but to ensure the horse moves in a straight line, the horse should be held from both sides. Treadmill exercise is thus not a labour saving option.

1.3.2 Non-ridden exercise (weight reduction).

Land treadmill exercise has the advantage over ridden exercise of allowing movement without increased load on the back or limbs. The weight of a rider increases peak vertical ground reaction forces in both forelimbs and hindlimbs but relatively more (50-100%) in the forelimbs than the hindlimbs [7,8]. Whilst the actual magnitudes of the increases in peak vertical ground reaction forces are small (1-5%) the weight of a rider has been shown to have significant effects on back posture [9]. In this study, a saddle loaded to 75 kg altered thoracolumbar posture in horses in walk, trot and canter by decreasing maximal flexion and increasing extension of the back without changing the overall range of movement of the back [9]. This is a significant consideration for rehabilitation of horses suffering from back pain or dysfunction. Rider weight also has an impact on distal limb kinematics. When the weight of a rider was added to horses exercising on a land treadmill, the loaded condition brought about an increase in relative stance duration and increases in maximal fetlock extension and maximal fetlock range of motion of both fore and hindlimbs [10] and so land treadmill exercise may be preferable to ridden exercise for fetlock/SDFT/suspensory ligament conditions.

Another alternative to unridden exercise is walking on a horsewalker, which is used for exercise or rehabilitation [11]. However, working the horse on a circle has the disadvantage of introducing asymmetry in limb inclination [12] and asymmetrical distal limb loading [13] which are contraindicated in various distal limb conditions. Hoof-ground interaction, degree of grip and slip, and risk of accidental injury may be influenced by the ground surface of the horsewalker [11].

1.3.3 Limb protraction-retraction.

There is an increase in limb retraction in both forelimbs and hindlimbs on a land treadmill belt when compared to overground exercise as the foot is drawn caudally by the moving belt in the stance phase [14]. This has the potential to increase strain on the accessory ligament of the deep digital flexor tendon (DDFT) at the end of stance phase [14] and presumably the deep digital flexor tendon at the same point in the stride cycle. Mendez-Angulo et al [15] measured maximal flexion/extension angles of distal limb joints on three different walking surfaces; hard ground, soft ground and a land treadmill in nine sound horses and found that maximal extension of both the fore and hind fetlocks was greater on a land treadmill when compared with both overground surfaces (approximately 5-10° greater). We recommend that DDFT injuries should not be rehabilitated on a land or water treadmill if alternative options are available due to the risk of increased strain caused by a prolonged retraction. However, the risk of a less than desirable movement pattern should be balanced against the risk of the alternative exercise options available for the case. We have rehabilitated forelimb DDFT injuries using a land treadmill at the owner's request because the horse was at greater risk of injury during in-hand walking. In some cases land treadmill exercise may not produce the ideal movement pattern but is still the better option at least in the short term until the horse becomes more settled as a result of an increase in work duration. Individuals with either hyperextended carpi ('back at the knee') or particularly straight hindlimb conformation seem to be more influenced by increased retraction on either land or water treadmill, and in these cases, treadmill exercise should be used with caution.

Increased hindlimb retraction leads to increased thoracolumbar extension [16], appearing to contraindicate the use of land treadmill exercise for horses with conditions such as impinging or over-riding dorsal spinous processes. In practice however, the flexion-extension range of movement (F-E ROM) of the back on a treadmill is comparable with that overground [17]. Whilst the measurement of F-E ROM does not distinguish between the ROM in flexion and the ROM in extension (i.e. a decrease in flexion and an increase in extension could result in the same total F-E ROM) the absolute differences in ROMs between overground and land treadmill locomotion were found to be small (< 1.0°). On this basis, land treadmill locomotion is not contraindicated for use in the rehabilitation of back dysfunction in horses and may provide certain benefits (see straight line exercise).

1.3.4 Firm surface.

The land treadmill provides a relatively firm surface, providing a greater propulsive force back to the limb during stance than a soft surface. Despite the increased hindlimb retraction of the limb on a land treadmill belt [14] it is commonly used in our Centre for hind limb injuries where the ability to exercise in a straight line on a firm surface is the primary requirement; e.g. in the 7-10 days post joint medication or for controlled exercise within the management of proximal suspensory desmitis. A comparison of distal limb joint ranges walking on three different surfaces showed that there were small but significant differences between tarsal extension on a land treadmill and walking overground [15]. In this study, tarsal extension on the land treadmill was actually lower than either of the other two surfaces (asphalt (hard) and a sand/loam arena surface (soft) which would support its use for hock injury rehabilitation but does seem slightly at odds with the knowledge that the hindlimb is relatively more retracted on a land treadmill than overground.

1.3.5 A level surface.

The nature of the land treadmill belt surface (being constant and level) is useful for exercising cases which require symmetry of loading of the foot. Foot imbalance is known to cause asymmetry of joint loading [18,19] which may be a contributing factor in the development of joint disease, ligament or tendon pathology in the foot. Addressing foot imbalance using corrective trimming and shoeing supports the treatment of joint pain using intra-articular medication. Following either corrective farriery and/or joint medication, straight line exercise on an even surface is recommended and the land treadmill provides one option for exercise in such scenarios.

1.3.6 Straight line exercise for horses with back dysfunction.

In horses with compromised spinal stability [20,21] and limited thoracolumbar flexion-extension range of movement as a result of back pain [22] exercise in a straight line is less demanding than movement on a circle, the latter requiring all three gross movement ranges (flexion-extension, lateral bend and axial rotation) to be controlled and coordinated. Movement on a circle causes increased activity in *longissimus dorsi* (LD) compared with movement in a straight line [23-25] and so working a horse with poor local spinal stability on a circle is likely to increase their reliance on global stabilisers such as LD, thereby limiting thoracolumbar flexion. We recommend that horses in the early stages of recovery from back pain and/or spinal surgery should not be exercised on the lunge until at least one month of exercise in straight lines supported by baited stretches and dynamic mobilisation techniques [21], static exercises (e.g. sternal lifts) and/or electrotherapy to retrain spinal stabilisers.

Some of the findings of Gomez Alvarez et al [17] study on back kinematics on a land treadmill compared with overground locomotion provide some additional, positive reasons for selecting land treadmill exercise even over other forms of non-ridden, straight line exercise for horses with back dysfunction. They found that the horizontal ROM (lateral bend) of the lumbar angles was less during land treadmill locomotion and the symmetry pattern of the lumbar vertebral angles was higher on a land treadmill. Exercise on a land treadmill is highly appropriate in the early stages of rehabilitation of back pain as it allows for thoracolumbar range in flexion (being riderless) whilst minimising lateral bend and axial rotation.

1.3.7 Use of incline/decline.

Loading of the forelimbs and hindlimbs can be affected by alterations in incline and decline of the land treadmill belt. Within our centre, small inclines (up to 3%) are used most often. Increasing incline leads to a shifting of weight and a shift in total ground reaction force (GRF) towards the hindlimbs [26] and is generally considered to be useful for developing hindlimb muscle strength, however a postural change towards increased thoracolumbar extension is a risk of inclined exercise due to increased hindlimb retraction on an incline compared with exercise on the level [27]. A shift in total ground reaction force towards the hindlimbs is evident in the degree of fetlock extension seen in fore and hindlimbs on an incline. Sloet van Oldruitenborgh-Oosterbaan et al [27] showed that, when trotting up an incline, there was a marked increase in maximal extension of the metatarsophalangeal (MTP) joint and decreased maximal extension of the metacarpophalangeal (MCP) joint. They suggested that horses with hind limb tendon problems should not be exercised uphill due to the higher tendon loading. We tend not to use inclines of more than 3% for hind limb suspensory ligament injuries for the same reason. The shift in GRF and the 'manner' of dealing with an incline does vary between horses. In a study on forelimb muscle activity and kinematics on a 0 and 8% incline [28], no such shift in MCP angle was seen. This was deemed to be as a result of the horses in this study 'pulling' rather than 'pushing' themselves up the slope and it was suggested that the posture adopted by the horse whilst moving on an incline should be taken into consideration when developing a training programme to ensure that horses are not 'forced into excessive lumbar extension'. In our experience, a slight decrease in speed (as compared to that on the level treadmill) is often necessary to ensure posture is not compromised when moving up an incline.

There is an increase in both intensity and duration of LD activity when horses exercise on an incline [24, 28]. Inclined exercise has implications for the activity and timing of hind limb muscle activity also. Robert et al [30] recorded the activity, onset, end and integrated electromyography (iEMG) signals from *gluteus medius* (GM) and *tensor fasciae latae* (TFL) during flat and inclined (3 and 6%) trotting. GM is a coxo-femoral joint extensor and a powerful hindlimb retractor, whilst TFL is antagonistic to GM in being a coxo-femoral joint flexor and a stifle stabiliser during stance [31]. The relative duration of activity of both decreased with incline but the iEMG of both muscles (but particularly TFL) increased with increasing incline. Exercise on an inclined land treadmill may therefore be useful for horses prone to upward fixation of the patella, as it preferentially recruits TFL thereby potentially helping to develop stifle stability. However, horses with unilateral upward fixation may benefit from work aimed at developing symmetry of muscle on the flat prior to inclined work, or risk simply 'over-developing' the unaffected limb.

Declined exercise is not used as readily as inclined exercise within either training or rehabilitation programmes, largely due to concerns about risk of injury resulting from increased loading of the forelimb and also because it does not confer the same training stimulus as level or inclined exercise. Hoyt et al [32] found oxygen uptake in horses trotting on a 10% decline was 45% lower than on the level. Declined locomotion requires eccentric muscle activity, and it is known from EMG studies in other species that eccentric muscle activity produces the same peak forces using a relatively smaller mass of active

The original publication is available at http://dx.doi.org/10.1016/j.jevs.2017.01.010
muscle than concentric muscle activity [33, 34]. Crook et al [35] found that mean EMG intensity of *GM* and *biceps femoris* in horses was lower during declined walking and trotting than on the level. Whilst it does not confer the same intensity or type of training stimulus to the cardiovascular and muscular systems as level or inclined work; downhill exercise may confer other benefits as described by Paulekas and Haussler [36] such as encouragement of hindlimb protraction and improvement of dynamic balance as the horse resists acceleration due to gravity. An increase in hindlimb protraction could potentially have benefits within rehabilitation programmes; but as yet; insufficient evidence exists to advocate its use and most land treadmills are not as readily declined as they are inclined.

## 2. Aspects of water treadmill exercise related to rehabilitation

### 2.1 Buoyancy

Buoyancy describes the upward force exerted on the horse equivalent to the volume of water displaced according to Archimedes principle. It has been estimated that the effective bodyweight of the horse is reduced by 10% with water at the level of the elbow/stifle, 30% at the level of the scapulohumeral joint and 75% at the level of the tubera coxae [37]. Levine et al [38] found that vertical ground reaction forces (vGRF) in dogs reduced by 9% after immersion to the tarsal joints, by 15% after immersion to the stifle joints and by 62% after immersion to the hip joints. Walking in high water therefore provides a suitable exercise for horses in which decreased vGRF is beneficial, e.g. dorsal metacarpal disease, rehabilitation following carpal or fetlock chip fracture and carpal osteoarthritis [39]. Progressive loading of the limbs throughout the rehabilitation programme can be brought about by progressively decreasing the exercising water depth. In our experience, high water (level of abdomen and above) can lead to loss of stability and 'rolling' in some horses. There is also a shift towards a higher thoracic limb to pelvic limb vGRF ratio with higher depth, whilst the absolute vGRF for the thoracic limb is still decreased from that experienced when the water level is below the level of the abdomen [38]. The horse's abdomen widens caudally and so the centre of buoyancy lies behind the centre of mass; this may contribute to a shift in weight towards the thoracic limb in higher levels of water and/or contributes to the increased tendency of the horse to 'roll' in high water.

### 2.2 Drag

Water is about 55 times more viscous than air. Viscosity results in a drag force which represents a resistance to forward progression. Drag forces are increased considerably with increased speed of swing of the limb. The faster the horse moves a limb forward through water, the greater the drag force experienced; hence why the comfortable walk speed for a horse in a water treadmill is much lower (up to 50% lower) than that on a land treadmill. This same goes for humans exercising on water treadmills [40]. The effect of drag is to increase the muscle forces placed on the limb and joints during the swing phase [38]. Preliminary data from our centre using inertial motion sensors [41] to track the range of movement of the metacarpus and metatarsus showed that forelimb protraction is progressively decreased as water depth increases, whilst hindlimb protraction is either unaffected or increased. The explanation for the difference between the two limbs lies in the difference in roles of the thoracic and pelvic limb and the nature of their muscular attachments. Overground, the protraction of the distal forelimb is largely passive due to the release of elastic energy stored in tendon springs [42]. During water walking, the increased resistance to limb protraction encourages the horse to rely more on *brachiocephalicus* to advance the forelimb [43]. Due to the impairment to the normal pendulum swing of the forelimb and our very early experiences of poor results with acute tendonitis, we do not recommend that water treadmill exercise is used for forelimb superficial digital tendon injuries until they are beyond the acute stage.

### 2.3 Hydrostatic pressure

High water results in greater hydrostatic pressure exerted on the distal limb which has potential benefits for certain disease conditions such as osteoarthritis (OA) [39]. Increased intra-articular pressure within an OA affected joint is thought to lead to decreased proprioception and impaired muscle function leading to loss of stability of the affected joint. Kamioka et al [44] suggested that afferent excitation of joint mechanoreceptors induced by increased intra-articular pressure (as in OA) may be dampened by the effects of increased hydrostatic pressure provided by aquatic therapy in human patients. OA human patients typically show abnormal postural sway patterns due to decreased joint stability and postural control [45]. King et al [46] conducted a study on the effect of a water treadmill programme on static postural sway in horses with induced carpal OA; finding that the postural stability of horses exercised 5 days a week for 8 weeks on a water treadmill was improved when compared to a control group exercised on a land treadmill.

2.4 Effects of water treadmill exercise on limb and back movement

The combination of buoyancy and drag experienced during water treadmill exercise produces a movement pattern which differs from both overground and land treadmill exercise. As water depth increases from a baseline (hoof depth), stride frequency is decreased and distal joint (metacarpo-phalangeal, metatarso-phalangeal, carpal and tarsal) flexion is increased [15] and there is an increase in flexion of the lumbar region of the back [47,48]. The range of hock movement produced during water treadmill exercise contraindicates its use for horses with tarsal synovitis.  In our Centre, water treadmill exercise has been used for horses with hind limb proximal suspensory desmitis (PSD) at the request of the vet in charge of the case. For these cases we use high water (i.e. hock joint or above) and a slow belt speed. High water may reduce the loading of the suspensory ligament in stance but will also increase the drag on the hindlimb with the potential to increase muscle development for protraction of the limb, while the relatively firm surface of the belt assists with energy return to the limb. Provided the horse is able to advance the limb sufficiently in high water there may be a rationale for using the water treadmill to reduce load within the suspensory whilst redeveloping hindlimb musculature. However, as so many PSD cases have multiple sites of lameness (for example, PSD in addition to sacro-iliac joint pain) this is definitely one to be judged on a case by case basis dependant upon the individual's movement pattern within the water.

At higher water depth the horse naturally has a higher head carriage in order to avoid submerging the nose, and in horses with a fixed and extended thoracic spine, water treadmill exercise in high water may actually exacerbate thoracic extension and is therefore contra-indicated for horses with mid-thoracic impinging or over-riding dorsal spinous processes [48]. Unless the water treadmill is being used primarily to provide a decreased weight bearing exercise, water at the level of the carpus/tarsus provides a useful compromise in promoting lumbar flexion (via the increased activity of the hindlimbs) whilst not inducing thoracic extension. The degree to which water treadmill exercise influences back kinematics is dependant, to a certain extent, on the horse's back conformation and existing thoracolumbar range of movement. As with any other movement dysfunction the fundamental limitation in movement range (whether it be soft tissue or bony in origin) needs to be addressed as fully as possible via medication, electrotherapy and/or manual therapy prior to the use of specific exercise aimed at development of an altered, more effective movement pattern. Water increases resistance to hindlimb protraction which may be beneficial in the development of sport horses required to 'engage' the hindlimb. The only caveat is that asymmetrical pelvic movement is likely to be exacerbated during water walking, so care should be taken to try and develop symmetry as far as possible prior to embarking on exercise aimed at muscle 'strengthening'.

The effect of water treadmill exercise on distal limb joints has some similarity with exercise over raised poles [49] presumably requiring muscle activation patterns that are also very different from walking overland or on a land treadmill. Due to the marked differences between water treadmill exercise and overground exercise, we would never use it as the sole form of exercise for any horse, no more than we would recommend a horse is only walked over raised poles.

Trotting in water necessitates a higher stride frequency (SF) than walking, with a resultant increase in forelimb muscle activity [43]. The increase in drag force during trotting seems to force the horse to adopt an extended thoracolumbar posture which is undesirable in rehabilitation of either thoracolumbar or hindlimb dysfunction. If heart rates were appreciably increased during trotting then it might serve as a useful substitute for canter work in racehorses/endurance horses, but from our work [4,5] and that of others [1,50] this does not seem to be the case. Even 25 minutes of trotting in total at either increasing speed or increasing water depth did not produce heart rate or blood lactate of over 143 bpm and 1.91 mmol/l [1] nor did a 4 week training programme of up to 20 minutes at 2.0 m/s produce any significant difference in $V_{200,}$ resting gluteal or superficial digital flexor muscle biochemistry [51]. Trotting in high water for 30 minutes (within 44 minute sessions) did not result in high blood lactate [52]. If the aim is decreased joint concussion with retention of a training stimulus, then swimming may be more appropriate as this results in higher heart rates (180 beats/min and above) [53]; however swimming (as with walking and trotting in high water) results in an extended thoracic posture so care should be taken so as not to exacerbate any back dysfunction, and simply shifting the horse's orthopaedic pain from the distal limb to the back.

2.5 Low intensity exercise.

Water treadmill exercise may provide a useful means of 'tapering' (the practice of reducing exercise prior to a competition) for racing Thoroughbreds. Tapering periods have been shown to improve performance in racehorses [54]. A taper of between 7 and 14 days within a prolonged training period may be beneficial in terms of maintaining performance and avoiding injury in Thoroughbred racehorses. The Thoroughbred horse has a tendency to a naturally high SF and is often more 'forward going', maintaining a higher SF on the water treadmill than other types of sport horses. Due to the nature of the drag force, this tends to be 'self limiting', in that the faster they try to swing the limb, the greater the resistance to movement. Evidence from the human literature suggests that the rate of perceived exertion during water walking is higher than the equivalent workload overground [55]. If the horse also experiences an increased perception of work done whilst water walking, this aspect of water treadmill exercise could be beneficial in maintaining the psychological well-being of the animal during rehabilitation involving prolonged periods of low intensity exercise.

### 3. Shoeing Considerations for Treadmill Exercise.

Shoes do not need to be removed for work on either land or water treadmill but modified shoes e,g, calkins and any toughened 'road' nails should be removed prior to work on a rubber belt as even at the walk they rapidly cause significant damage to the rubber belt. Care should be taken when working unshod horses daily or twice daily on a land treadmill for a prolonged period as the hind foot cannot slide into stance on a rubber belt [56] and this can cause excessive hoof wear and sore feet. One of the advantages of land treadmill exercise is that increased shoe length and/or width can be more boldly applied since the horse will not be exposed to uneven or deep surfaces and does not need to turn. The effect of shoeing modifications are easily observed on a land treadmill, aiding decision-making regarding the best type of shoe to use to support the horse's rehabilitation. The use of a land treadmill also enables easier and more controlled application of weights and chains for alteration of hindlimb gait [57]. In a water treadmill, shoes with significant lateral extensions can increase the drag force in the water, substantially altering the limb flight. If a horse is fitted with large extensions we do not recommend the use of water treadmill exercise.

Although we have not experienced hoof problems following water treadmill use, this has been reported from a few venues. This could potentially be related to individual hoof condition or frequency of water treadmill exercise. Hooves should be checked for wounds or defects that might be a contraindication for water treadmill use. Routine hoof care would be recommended between sessions.

## 4. Moving on from treadmill exercise and preparation for ridden work.

Horses subject to prolonged periods of box rest and/or walking exercise have a tendency to descend into an extended spinal posture with an elongated abdominal line. Since the role of rectus abdominis (RA) is to limit thoracolumbar extension when a horse lands from suspension (and hence RA is more active in trot (with a suspension phase) than in walk (no suspension) [58,59], it seems inevitable that restriction to box rest and/or walking exercise alone will predispose the horse to an extended thoracolumbar posture. The simplest means of rectifying this is to use trot within the exercise programme. However, whether trot work is possible is dictated by the most limiting orthopaedic issue. In cases where trotting is not possible but tension in the 'string' is to be maintained, therapists often advocate various techniques to maintain abdominal muscle strength such as the use of baited stretches and sternal lifts, lateral bending/slalom exercise in walk or walking over raised poles. In our experience, regaining abdominal muscle strength and the ability to flex the thoracolumbar spine prior to ridden work is of paramount importance for a successful return to ridden work. For many cases a suitable progression from land treadmill exercise would be ground schooling (in straight lines in walk and trot) prior to lungeing in all three gaits followed by ridden work. In certain cases safety considerations may take precedent over optimal postural development and horses may go straight from land treadmill to ridden work if it is suspected they will be difficult to manage safely during ground schooling. Generally, it is beneficial to reintroduce a variety of surfaces and loading patterns before returning to normal ridden exercise for the purpose of enhancing proprioceptive and neuromuscular function.

## 5. Conclusion

Land treadmill exercise provides the opportunity to exercise a horse on a firm level surface in a straight line with a high degree of control. It has potential benefits for the rehabilitation of many and varied orthopaedic conditions. Work to date shows that water treadmill exercise produces profoundly different movement patterns to walking overland or on a land treadmill and should be considered more challenging for the horse than land treadmill exercise. If a client has a treadmill and wants to use it, the veterinary surgeon in charge of the case should advise based on evidence and clinical reasoning coupled with observation of the individual horse's gait pattern whilst carrying out the exercise. Teaming up with an experienced and suitably qualified therapist who can assist in development of a coordinated exercise and treatment programme may be beneficial. Regular monitoring of the gait pattern throughout rehabilitation either by therapist/vet or both is recommended.

**Acknowledgements**

Thank you to Gillian Tabor MCSP, ACPAT Cat A and Andrew Harrison, BVSc, CertEP, CertVA, MRCVS for their valuable comments on the manuscript.

## 6. References

1. Lindner A, Wäschle S, Sasse HHL. Physiological and blood biochemical variables in horses exercising on a treadmill submerged in water. J Anim Physiol Anim Nut 2012; 96: 563-9.
2. King CM, Evans DL, Rose RJ. Acclimation to treadmill exercise. Equine Vet J 1995; 27(S18):453-6.
3. Buchner HHF, Savelberg HHCM, Schamhardt HC, Merkens HW, Barneveld A. Habituation of horses to treadmill locomotion. Equine Vet J 1994; 26(S17): 13-5.
4. Nankervis KJ, Williams RJ. Heart rate responses during acclimation of horses to water treadmill exercise. Equine Vet J 2006; 38: 110-2.
5. Scott R, Nankervis K, Stringer C, Westcott K, Marlin D. The effect of water height on stride frequency, stride length and heart rate during water treadmill exercise. Equine Vet J 2010; 42: 662-4.
6. Franklin SH, Barakzai SZ, Courouce-Malblanc A, Dixon P, Nankervis KJ, Perkins JD, et al. Investigation of the incidence and type of injuries associated with high-speed treadmill exercise testing. Equine Vet J 2010; 42(S38): 70-5.
7. Schamhardt HC, Merkens HW, Van Osch GJVM. Ground reaction force analysis of horses ridden at the walk and trot. Equine Exerc Physiol 1991; 3: 120-7.
8. Clayton HM, Lanovaz JL, Schamhardt HC, van Wessum R. The effects of a rider's mass on ground reaction forces and fetlock kinematics at the trot. Equine Vet J 1999; S30: 218-21.
9. De Cocq PD, Van Weeren PR, Back W. Effects of girth, saddle and weight on movements of the horse. Equine Vet J 2004; 36: 758-763.
10. Oldruitenborgh-Oosterbaan, MMS, Barneveld A, Schamhardt HC. Effects of weight and riding on workload and locomotion during treadmill exercise. Equine Vet J 1995; 27: 413-17.
11. Walker TJ, Collins SN, Murray RC. Horse walker use in dressage horses. Comp Exerc Physiol 2012; 8: 63-70.
12. Hobbs SJ, Licka T, Polman R. The difference in kinematics of horses walking, trotting and cantering on a flat and banked 10 m circle. Equine Vet J 2011; 43*:* 686-94.
13. Davies HMS, Merritt JS. Surface strains around the midshaft of the third metacarpal bone during turning. Equine Vet J 2004; 36: 689-92.
14. Buchner HH, Savelberg HH, Schamhardt HC, Merkens HW, Barneveld A. Kinematics of treadmill versus overground locomotion in horses. Vet Q 1994; 16 (S2): 87-90.
15. Mendez-Angulo JL, Firshman AM, Groschen DM, Kieffer PJ, Trumble TN. Impact of walking surface on the range of motion of equine distal limb joints for rehabilitation purposes. Vet J 2014; 199: 413-8.
16. Denoix JM. Spinal biomechanics and functional anatomy. The Veterinary Clinics of North America. Equine Practice. 1999; 15: 27-60.
17. Álvarez, CB, Rhodin M, Byström A, Back W, Weeren PV. Back kinematics of healthy trotting horses during treadmill versus over ground locomotion. Equine Vet J 2009; 41: 297-300.

18. Denoix JM. Functional anatomy of the equine interphalangeal joints. Proc Am Assoc Equine Pract. 1999; 45: 174-7.
19. Viitanen MJ, Wilson AM, McGuigan HP, Rogers KD, May SA. Effect of foot balance on the intra-articular pressure in the distal interphalangeal joint in vitro. Equine Vet J 2003; 35: 184-9.
20. Stubbs NC, Riggs CM, Hodges PW, Jeffcott LB, Hodgson DR, Clayton HM, Mc Gowan CM. Osseous spinal pathology and epaxial muscle ultrasonography in Thoroughbred racehorses. Equine Vet J 2010; 42: 654-61.
21. Stubbs NC, Kaiser LJ, Hauptman J, Clayton HM. Dynamic mobilisation exercises increase cross sectional area of musculus multifidus. Equine Vet J 2011; 43: 522-9.
22. Wennerstrand J, Johnston C, Roethlisberger-Holm K, Erichsen C, Eksell P, Drevemo S. Kinematic evaluation of the back in the sport horse with back pain. Equine Vet J. 2004; 36: 707-11.
23. Wakeling JM, Barnett K., Price S, Nankervis K. Effects of manipulative therapy on the longissimus dorsi in the equine back. Equine Comp Exerc Physiol 2006; 3: 153-60.
24. Wakeling JM, Ritruechai P, Dalton S, Nankervis K. Segmental variation in the activity and function of the equine longissimus dorsi muscle during walk and trot. Equine Comp Exerc Physiol 2007; 4: 95-103.
25. Cottriall S, Ritruechai P, Wakeling JM. The effects of training aids on the longissimus dorsi in the equine back. Comp Exerc Physiol. 2008; 5: 111-4.
26. Dutto DJ, Hoyt DF, Cogger EA, Wickler SJ. Ground reaction forces in horses trotting up an incline and on the level over a range of speeds. J Exp Biol 2004; 207: 3507-14.
27. Oldruitenborgh-Oosterbaan MM, Barneveld A, Schamhardt HC. Effects of treadmill inclination on kinematics of the trot in Dutch Warmblood horses. Equine Vet J. 1997; 29(S23):71-5.
28. Hodson-Tole Effects of treadmill inclination and speed on forelimb muscle activity and kinematics in the horse. Equine Comp Exerc Physiol 2006; 3:61-72
29. Robert C, Valette JP, Denoix JM. The effects of treadmill inclination and speed on the activity of three trunk muscles in the trotting horse. Equine Vet J 2001; 33:466-72.
30. Robert C, Valette JP, Denoix JM. The effects of treadmill inclination and speed on the activity of two hindlimb muscles in the trotting horse. Equine Vet J 2000; 32:312-7.
31. Tokuriki M, Aoki O. Electromyographic activity of the hindlimb muscles during the walk, trot and canter. Equine Vet J. 1995; 27: 152-5.
32. Hoyt DF, Wickler SJ, Garcia SF. Oxygen consumption (VO2) during trotting on a 10% decline. Equine Vet J 2006; 38(S36): 573-6.
33. Gillis GB, Biewener AA. Effects of surface grade on proximal hindlimb muscle strain and activation during rat locomotion. J App Physiol 2002; 93: 1731-43.
34. Gabaldón AM, Nelson FE, Roberts TJ. Mechanical function of two ankle extensors in wild turkeys: shifts from energy production to energy absorption during incline versus decline running. J Exp Biol 2004; 207:2277-88.
35. Crook TC, Wilson A, Hodson-Tole E. The effect of treadmill speed and gradient on equine hindlimb muscle activity. Equine Vet J 2010; 42(S38): 412-6.

36. Paulekas R, Haussler KK. Principles and practice of therapeutic exercise for horses. J Equine Vet Sci. 2009; 29: 870-93.
37. McClintock SA, Hutchins DR, Brownlow MA. Determination of weight reduction in horses in flotation tanks. Equine Vet J 1987; 19: 70-1.
38. Levine D, Marcellin-Little DJ, Millis DL, Tragauer V, Osborne JA. Effects of partial immersion in water on vertical ground reaction forces and weight distribution in dogs. Am J Vet Res 2010; 71: 1413-6.
39. King MR, Haussler KK, Kawcak CE, McIlwraith CW, Reiser RF. Mechanisms of aquatic therapy and its potential use in managing equine osteoarthritis. Equine Vet Educ 2013; 25:204-9.
40. Evans BW, Cureton KJ, Purvis JW. Metabolic and circulatory responses to walking and jogging in water. Res Q Exerc Sport. 1978; 49: 442-9.
41. Lefrancois K. Equine distal limb range of motion during water treadmill walking. MSc Thesis. 2015 Hartpury University Centre, Glos. UK.
42. Back W, Schamhardt HC, Savelberg HHCM, van den Bogert AJ, Bruin G, Hartman W, et al. How the horse moves: 1. Significance of graphical representations of equine forelimb kinematics. Equine Vet J 1995; 27: 31-8.
43. Tokuriki M, Ohtsuki R, Kai M, Hiraga A, Oki H, Miyahara Y, et al. EMG activity of the muscles of the neck and forelimbs during different forms of locomotion. Equine Vet J 1999; S30: 231-4.
44. Kamioka H, Tsutani K, Okuizumi H, Mutoh Y, Ohta M, Handa S, et al. Effectiveness of aquatic exercise and balneotherapy: a summary of systematic reviews based on randomized controlled trials of water immersion therapies. J Epidemiol 2010; 20: 2-12.
45. Messier SP, Royer TD, Craven TE, O'Toole ML, Burns R, Ettinger WH. Long-term exercise and its effect on balance in older, osteoarthritic adults: Results from the Fitness, Arthritis, and Seniors Trial (FAST). J Am Geriatr Soc 2000; 48: 131-8.
46. King MR, Haussler KK, Kawcak CE, McIlwraith CW, Reiser II RF. Effect of underwater treadmill exercise on postural sway in horses with experimentally induced carpal joint osteoarthritis. Am J Vet Res 2013; 74: 971-82.
47. Mooij MJ, Jans W, Den Heijer GJ, De Pater M, Back W. Biomechanical responses of the back of riding horses to water treadmill exercise. The Vet J 2013; 198: 120-3.
48. Nankervis K, Finney P, Launder L. Water depth modifies back kinematics of horses during water treadmill exercise. Equine Vet J 2016; http://dx.doi.org/10.111/evj.12519
49. Brown S, Stubbs NC, Kaiser LJ, Lavagnino M, Clayton HM. Swing phase kinematics of horses trotting over poles. Equine Vet J 2015; 47:107-12.
50. Voss B, Mohr, E, Krzywanek H. Effects of aqua-treadmill exercise on selected blood parameters and on heart rate variability. J. Vet. Med. Assoc. 2002; 49: 137-143.
51. Borgia L A, Valberg SJ, Essen-Gustavsson B. Differences in the metabolic properties of gluteus medius and superficial digital flexor muscles and the effect of water treadmill training in the horse. Equine Vet J 2010; 42(S38): 665-70.

52. Vincze A, Szabó C, Szabó V, Veres S, Ütő D, Hevesi Á. The Effect of Deep Water Aqua Treadmill Training on the Plasma Biochemical Parameters of Show Jumpers. Agri Conspec Sci 2013; 78: 289-93
53. Misumi K, Sakamoto H, Shimizu R. Changes in blood lactate and heart rate in thoroughbred horses during swimming and running according to their stage of training. Vet Rec 1994; 135: 226-8.
54. Shearman JP, Hamlin MJ, Hopkins WG. Effect of tapered normal and interval training on performance of Standardbred pacers. Equine Vet J. 2002; 34: 395-9.
55. Svedenhag J, Seger J. Running on land and in water: comparative exercise physiology. Med Sci Sports Exerc 1992; 24: 1155-60.
56. Roepstorff L, Johnston C, Drevemo S. The effect of shoeing on kinetics and kinematics during the stance phase. Equine Vet J 1999; S30: 279-85.
57. Clayton HM, Lavagnino M, Kaiser LJ, Stubbs NC. Evaluation of biomechanical effects of four stimulation devices placed on the hind feet of trotting horses. Am J Vet Res 2011; 72:1489-95.
58. Robert C, Valette JP, Denoix JM. Surface electromyographic analysis of the normal horse locomotion: a preliminary report. Proc Conf Equine Sports Med Sci 1998 ; 80 (85).
59. Zsoldos RR, Kotschwar A, Kotschwar AB, Rodriguez CP, Peham C, Licka T. Activity of the equine rectus abdominis and oblique external abdominal muscles measured by surface EMG during walk and trot on the treadmill. Equine Vet J 2010; 42(S38): 523-9.

Table 1.: Recommendations and contra-indications for the use of treadmill exercise in rehabilitation

| **LAND TREADMILL EXERCISE** | |
|---|---|
| **YES** | **NO** |
| Acute SDFT injury | Acute DDFT injury |
| Post treatment for impinging or over-riding dorsal spinous processes on flat and inclines < 3° | DIP joint pain |
| Sacro-iliac region pain | |
| Suspensory desmitis (fore and hind limb) (but not inclines >3° for hindlimb cases) | Horses with hindlimb suspensory desmitis and particularly straight hind limb conformation (in combination) |
| Upward fixation of the patella (including incline) | Unilateral upward fixation with marked muscle asymmetry. |
| **WATER TREADMILL EXERCISE** | |
| **YES** | **NO** |
| SDFT injury post ~ 1 mo | Acute SDFT or DDFT tendonitis |
| Post treatment for impinging or over-riding dorsal spinous processes (avoiding high water for cases affected in mid-thoracic region) | Hock joint pain |
| Sacro-iliac region pain (post acute phase) | Wounds |
| Proximal suspensory desmitis (fore)<br>Proximal suspensory desmitis (hind) use with care | |
| Distal limb chip fracture rehabilitation | Skin conditions |