International survey of equine water treadmills – why, when and how?

Carolyne A Tranquille*, Jack B Tacey, Vicki A Walker, Kathryn J Nankervis^ and Rachel C Murray.

Centre for Equine Studies, Animal Health Trust, Kentford, Newmarket, Suffolk, CB8 7UU, UK; ^Equestrian Performance Research and Knowledge Exchange Arena, Hartpury University Centre, Gloucester GL19 3BE.

*Corresponding author: carolyne.tranquille@aht.org.uk

The final version of this article was published in the Journal of Equine Veterinary Science and can be accessed at https://doi.org/10.1016/j.jevs.2018.05.220

Conflict of interest

None to declare.

Abstract

Water treadmills (WT) are becoming increasingly popular as rehabilitation and training tools. Concerns have been raised amongst equine professionals about injury development/exacerbation following WT use, and little knowledge of optimal WT use is available. The aim of this study was to determine how WTs are being used, using an international survey based approach, with a view to informing future research. Venues were identified through internet searches and WT manufacturers. A questionnaire inquired about venue set-up, caseload overview and protocol overview. A case-specific questionnaire generated information about individual sessions. One hundred and twenty venue questionnaires were distributed and 41 responses (34%) were obtained; nine of these venues contributed 608 case-specific questionnaires. WT's were found mostly at educational and rehabilitation centres, with four on private yards. Horse fitness, previous experience, age, weight and veterinary condition influenced individual protocols. All centres habituated their cases for 2-3 sessions, for an average of 16min in hock or fetlock depth water. Significant differences between training and rehabilitation sessions were identified (deeper

water, slower walk speed and longer duration for training compared to rehabilitation; P≤0.023 for all three variables). WT's were most frequently used for rehabilitation in horses with ligament and tendon injuries. WT habituation is important and protocols were similar between venues. WT's usage was 60%:40% between training:rehabilitation with protocols varying significantly between venues.

Keywords: Equine; Water treadmill; Rehabilitation; Usage patterns; Protocols

Highlights

- There are concerns about injury development following water treadmill (WT) use.
- This study aimed to determine how WTs are being used for horses.
- Horse fitness, age, weight and veterinary condition influence individual protocols.
- Significant differences between training and rehabilitation sessions identified.
- WTs were frequently used for rehabilitation in horses with soft tissue injuries.

1. Introduction

The use of water treadmills (WT) has increased in the last 10 years with anecdotal reports indicating that it is a popular cross training tool within the sport horse community in the United Kingdom (UK). Water treadmills provide a means of exercising a horse on a straight line and on a firm surface, without the additional weight of the rider, and the added benefit of some reduction in weight bearing due to buoyancy when deep water is used during an exercise session [1-2]. In addition to these fundamentals of WT exercise, recent work has described other potential benefits. Studies using horses with experimentally induced carpal osteoarthritis found some improvement in postural sway [3] and improved thoracic limb function, joint range of motion and synovial membrane integrity [4]. Studies carried out on horses have also shown increased range of movement of distal limb joints [5], decrease in stride frequency [6] and increased lumbo-pelvic flexion [7-8] with increasing water depth, perhaps explaining why this form of exercise is becoming favoured within the training programmes of dressage horses, as trainers seek to develop gait characteristics associated with 'good performance' [9].

However, WT exercise also has certain potential disadvantages. Potential risks of WT exercise include: injury to horse or handler during the process of introducing the horse to WT exercise or skin problems [7]. Intense muscle activity could potentially lead to uneven or over development of specific forelimb muscles [10], the potential to exacerbate injury as a result of overloading vulnerable structures [2] or the development of inappropriate 'head up' and extended thoracic posture [8]. Within the literature, protocols used in WT studies range widely in terms of speed (slow walk to fast trot) and the water depth used (from hoof to 80% wither height) [1]. The risk of any negative effects of WT exercise in practice is as yet unknown, nor is it known how to select the right combination of belt speed and water depth for best effect within any given training or rehabilitation programme.

There is some evidence that a further variable which influences the responses to WT exercise is the horse's individual movement pattern. Nankervis et al. [8], found differences in individual horse's pelvic movement patterns with increasing water depth. Of a group of competition horses believed to be sound, six out of 13 horses showed the greatest pelvic displacement in water at stifle depth whereas seven out of 13 horses showed the greatest pelvic vertical displacement at hock depth or even lower. Mooij et al. [7] observed horses over the course of 10 days water walking, and found no significant changes in axial rotation, lateral bend or pelvic flexion between day 1 and day 10, implying that there was no detectable training effect on the movement of the back, despite some of the horses appearing to change their movement pattern on visual inspection. They concluded that fixed protocols may not be optimal given individual horse's patterns of pelvic movement. Both these studies show that different movement patterns may be induced by the same combination of water depth and belt speed, and so an individual horse's responses to WT exercise should be monitored both within a session and over time to ensure that the horse is responding in a way that supports the aims of the training or rehabilitation programme.

Given that the evidence to date shows the potential for both positive and negative effects of WT exercise, the purpose of this study was to determine how WTs are currently being used in practice; whether exercise sessions are adapted for training or rehabilitation purposes, and whether such adaptations are believed to be successful as perceived by the owner/rider; with a view to informing future experimental studies. Using a questionnaire-based approach, the specific aims were to describe: 1, equine WT usage patterns; 2. Habituation, training and rehabilitation protocols; 3. Owner perception of WT exercise.

2. Materials and Methods

2.1 Ethical Review

The study was approved by the Ethical Review Committee of the Animal Health Trust (project number: AHT30-2015). All respondents consented to taking part and publication of the results.

2.2 Questionnaire design

Three questionnaires were designed:

1. Venue information: A single questionnaire per WT venue, which requested details of the venue itself and a summary of the case load and protocols used at that particular venue;
2. Individual horse information: Multiple questionnaires were completed by venues relating to specific details of the individual horses and protocols used within a two week time period;
3. Horse owner information: This requested details from horse owners/users on why they use WTs and their impression of their horse's responses to WT exercise.

All questionnaires were available online or on paper for completion. To minimise potential bias, particular attention was paid to the wording of the questions to achieve explicit understanding by participants. The variables collected are listed in Table 1 and copies of the questionnaires can be viewed in the supplementary material.

2.3 Sample population selection

Pilot questionnaires were developed and tested on a small number of horse owners and venues with a WT. For the final versions of the questionnaires, venues with WTs were sourced through internet searches, veterinarians, horse owners/trainers and through equine WT manufacturers. Pre-tested questionnaires were sent to equine WT manufacturers to distribute to their clients.

Venues identified by the authors were contacted directly and provided with links or paper copies of the final questionnaires. The study was advertised through social media with links to the online questionnaire, and members of sport horse disciplines were also provided with access to the questionnaires. A prize draw and postage paid envelopes were used as incentives for questionnaire completion and return.

2.4 Data input

Data from online questionnaires were downloaded automatically into a database (Microsoft Excel). All the details from the paper questionnaires were manually entered into that same database once the questionnaire was closed. Data were cross checked for accuracy.

2.5 Statistical analysis

Descriptive analysis was undertaken for all elements of the questionnaire. A chi-squared test was used to determine if water depth (deep versus shallow: deep included hock/carpus level and above and shallow included all depths below hock and carpus) was significantly different between training and rehabilitation sessions. A t-test or Mann-Whitney were used (as appropriate) to determine if there were difference in mean walk speed and mean total session duration between training and rehabilitation sessions. All statistical analyses were performed using a statistical software package (Analyse-it, version 3 for Microsoft Excel 2000) with a significance level of $P<0.05$.

3. Results

One hundred and twenty venues worldwide were identified through internet searches, or contact through WT manufacturers, veterinarians and horse owners. For Questionnaire 1, a total of 41 responses (34%) were collected. The greatest numbers of responses (44%) were from the UK (Figure 1). For Questionnaire 2, 608 responses were collected from nine venues that completed Questionnaire 1. One hundred and seven responses were collected for Questionnaire 3.

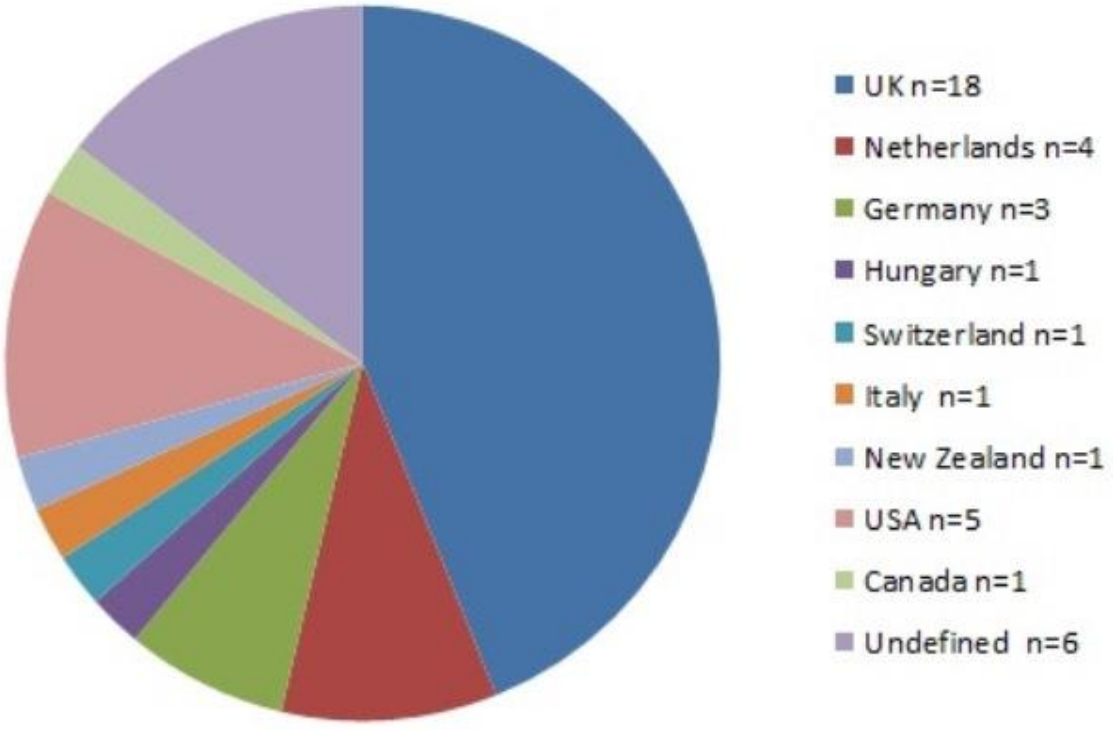

Figure 1: Pie chart showing the number of responses received per participating country.

3.1 Questionnaire 1: Venue Information

The three most frequently owned machine types were FMBs Activomed (40%), Formax Aqua Icelander (11%) and the Horsegym Aquatrainer (11%) and were most frequently located in a

quiet and low activity area (71%). The Activomed machines were only found in the UK. Venues had owned their WT for an average of 60 months (range: 0.5-300). In 92% of the venues the horse was unloaded going forwards. In 83% of the venues the handlers were trained in-house and horses were held from both sides in 63% of the venues. Thirty-six respondents used fresh water and five used salt water (four in the UK and one in North America). Twenty-one venues changed the water after five or more single horse exercise sessions, five venues changed the water after every session and three venues never changed the water. Venues that recycled the water used filtration systems (including sand and carbon systems) (71%), ultraviolet (UV) radiation units (52%) or a water purifier (5%). Venues that chemically cleaned their water most frequently used sodium hypochlorite (75%) and chlorine (50%). Fourteen of the respondents indicated they controlled the water temperature (mean: 13°C/55°F; range: 4-24°C/39-75°F); reasons given for controlling the water temperature included veterinary condition, standard protocol, previous horse WT experience and to prevent microbial growth.

Fourteen venues sedated and/or used calmers. Reasons included: difficult horse (24%), habituation session (22%), owner request (8%), when it was merited (3%) or if the horse was injured (3%). Injection was the most frequently used technique (43%) followed by oral paste (7%) and injection and tablet (7%); six of the venues did not report their technique. Six venues did not specify what was used as sedation. Romifidine was most frequently used (29%), followed by detomidine (14%), acepromazine (7%) and a combination of acepromazine and romifidine (7%).

All participating venues indicated that session type (habituation, training or rehabilitation), veterinary condition, horse fitness/previous experience/age/weight all significantly influenced the session duration, water depth and speed used for an individual horse. An individual horse

would have an average of seven exercise sessions per week (range: 0-14). Only 24% (n=10) of the respondents required a veterinary referral prior to undertaking any kind of WT exercise.

Prior to using a WT the horses legs were washed, the hooves were picked out and the tail bandaged at all responding venues. Forty-five percent of centres actively warmed the horse up (horse walker, hand walking, lunging, ridden exercise, slow walking in a pool or using a dry treadmill) and 20% passively warmed the horse up (a solarium or massage rug). After WT exercise all venues washed the horse off and either scraped the horse, towel dry or dried off in a solarium/under heaters. Four venues disinfected the legs and one venue greased the hooves.

Twenty-four venues reported no accidents involving their WT, 15 venues reported injury to the horse and three venues reported injuries to the handlers during WT exercise. Three venues reported damage to the WT during an accident. There was an impression of development or deterioration of various orthopaedic/lameness conditions in conjunction with WT exercise, although these could not necessarily be directly attributed directly to use of the WT. Skin conditions were the most frequently reported adverse effect after using a WT (14%). Other reported adverse effects, as perceived by WT operators, included: horse stiffening, fungal conditions, lameness, a rash, frog injuries, changes to movement patterns, ligament or tendon injury and hoof wall softening. It was reported that there had been exacerbation of one case of each of the following: tendon injury, back problem and mud fever during a WT exercise programme.

3.2 Questionnaire 2: Individual Horse Information

Six hundred and eight case-specific questionnaires were completed from nine venues: eight in the UK (two colleges (71%), one private showjumping yard (4%) and five rehabilitation centres

(20%)) and one rehabilitation centre in the Netherlands (5%). Seventy-three percent of these questionnaires were collected retrospectively by one of the authors (JBT) from four UK venues (two colleges and two rehabilitation centres).

3.2.1 Habituation

Seven of the venues took between two and three sessions of 'habituation' to accustom the horse to the speed and depth of water required for exercise; one venue did not carry out any habituation sessions during the data collection period. Habituation sessions typically ranged from 10-30min in duration with the water depth slowly increasing to the level of the hock by the end of the second or third session depending on the venue. The average walk speed was 1.6m/s (range: 0.7-2.8). One venue trotted their cases during habituation with a mean speed of 4.4m/s (range: 3.9-4.9). Seventy percent of the cases were sedated for first time only (n=21) and 30% of the cases were also sedated for the second session.

3.2.2 Training

Sixty percent of the case-specific responses were for training protocols, mainly sports horses (32% dressage, 16% eventing and 8% show jumping). Hock depth water was most frequently used (24%) (Table 2), average walk speed was 1.6m/s (range: 0.7-3) and average trot speed was 4.4m/s (range: 3-5). The mean total session duration was 23.5min (range: 5-54) (Table 3). The two main outcomes of a session were an impression of increased strength/condition/fitness (62%) and an improvement in general performance (57%) as perceived by the owner/rider (Table 4).

3.2.3 Rehabilitation

226 The main reported applications of WT exercise were for rehabilitation of suspensory ligament
227 and tendon injuries (41%) (Table 5). Mid-cannon (25%) and above the fetlock (24%) water
228 depths were most frequently used (Table 6) with a mean walk speed of 1.75m/s (range: 0.7-
229 2.8). Two venues trotted their cases at a mean speed of 4.3m/s (range: 3.4-5). The mean session
230 duration was 22.5min (range: 5-40) (Table 7).
231
232 **3.2.4 Comparison between training and rehabilitation sessions**
233 A significantly greater proportion of training sessions used deep water compared to the
234 rehabilitation sessions (P=0.022). Mean walk speed was significantly greater for rehabilitation
235 sessions compared to training sessions (P=0.001) and mean session duration was significantly
236 longer for training sessions (P=0.023).
237
238 **3.3 Questionnaire 3: Horse Owner Information**
239 One hundred and seven responses were collected for 21 venues. The main reasons for using a
240 specific venue was a recommendation (66%) and the location/distance from their home (52%)
241 (Table 8). Improved performance (77%) and improved strength and muscle development
242 (38%) were the most frequently reported owner perceived positive changes with WT exercise
243 (Table 9). There also were a small number of negative outcomes (Table 10) reported by owners
244 which included improving the horse's performance past the riders' ability (2%).
245

4. Discussion

This study describes how equine WTs are being used in practice, and the protocols used for habituation, training and rehabilitation. Information was gathered on individual horse WT use and owner perceived benefits of WT exercise. To our knowledge this is the first time such a study has been conducted and therefore provides novel information.

The results showed that the average age of a WT was 60 months, with the minimum age being 0.5 months and maximum age being 300 months. This suggests, and supports anecdotal reports, that WT production and usage may have increased in the last five years, and supports the subjective impression of recent increased use in equine rehabilitation and training programmes. Our study indicated that the three most frequently owned machine types were FMBs Activomed, Formax Aqua Icelander and the Horsegym Aquatrainer. Obviously these results have a level of bias, in that we tried to distribute questionnaires through various manufacturers, and because most data was collected from the UK. However, we were relatively unsuccessful in this distribution in comparison with other methods of access to venues and individuals, so the level of bias is likely to have been limited. Activomed machines are marketed and sold by a company that also supply and sell a number of equine therapy systems and equipment. A number of UK International riders' use their products which could explain why they are the most common machine in the study as the majority of the respondents were based in the UK. The Formax machines are manufactured by a small company based in Iceland but have clients based in numerous countries. The Horsegym machines are manufactured in Germany but their client list covers numerous elite level riders, from all disciplines, from a number of European countries and in the United States of America. This might explain why they are the third most frequently owned machine type.

Machine design could potentially affect how a horse moves and works when on a WT. In approximately two thirds of the respondents the horse could be held from both sides meaning the horse would be straight when in the WT. However if a horse was held on one side only there would be potential for the horse to lose straightness and be bent towards the side of the handler. The intensity and duration of the electromyographic activity of the *brachiocephalicus* can be increased on the side adjacent to the handler when horses were held from one side only [Nankervis et al., unpublished data]. This may be an aspect that WT operators need to be aware of if the aim of a WT session was to improve the straightness of a particular horse.

In the current study, five of the respondents used salt water in their treadmills; however there is no evidence to support the use of fresh water over salt water in an equine WT. An Italian study indicated that for people suffering from osteoarthritis, salt spa therapy resulted in a significant reduction in hospital admissions, physical and pharmacological therapies, and work absences in the year following treatment compared to prior [11]. Recent studies showed that spa water, with a high percentage of sodium, reduced parameters associated with chronic inflammatory skin disease [12] and respiratory disease [13]. There are anecdotal reports suggesting that salt water used in equine spas acts as a hypertonic poultice and reduces heat and inflammation around an injury; however there are no such reports from operators of salt water equine WTs.

In human studies of WT exercise, water temperature ranged from 28 to 32°C [14-20] and in canine studies the temperature ranged from 30 to 35°C [21-22]. In contrast in equine studies the water temperature ranged from 13 to 22°C [1, 11, 23-26]. The temperature ranges reported by the respondents in the current study have a much lower minimum temperature (4°C). The differences could be explained by how/where the water was stored and the time of year the

296 previous studies took place. Water has greater thermal conductivity than air and can therefore
297 have a significant effect on body temperature. A previous study [24] investigating the effect of
298 different water temperatures on heart rates in horses indicated that exercising in water at higher
299 temperatures (19°C) induced a higher heart rate than exercising in colder water (13°C); the
300 authors suggested that cardiovascular drift was likely to occur when exercising in 19°C water.
301 It appears that water temperature could potentially be an important factor to consider, with
302 respect to session duration, when designing WT sessions. The variation in temperatures that
303 we have found in our study suggests that further studies to investigate the effect of different
304 water temperatures are warranted.
305
306 All venues had procedures in place to reduce water contamination which included washing the
307 horse, catching faeces during the WT session (using nappies or a net) and water filtration
308 systems. Washing the horses' legs and catching faeces are simple procedures that can reduce
309 the presence of large debris in the water which could potentially block the filtration unit.
310 Filtration systems (sand and carbon) and UV units were most frequently used to recycle water.
311 Sand systems remove suspended solids from the water, carbon systems also remove impurities
312 by chemically bonding to the carbon as it passes through the filter. There are anecdotal reports
313 that UV radiation can eliminate 99.99% of bacteria and viruses present in the water, however
314 it would not eliminate suspended solids from the water. One of the WT manufactures
315 recommend using a filtration and UV system as anecdotal reports suggest that using a filtration
316 system, in combination with a UV unit, would be the optimum method of recycling water for
317 WT usage.
318
319 The current study indicated that sodium hypochlorite and chlorine were most frequently used
320 to treat the water. Sodium hypochlorite is an anti-microbial that is frequently used as a

disinfectant in human health care facilities [27]. Chlorine is used to kill bacteria in swimming pool water and is essential in controlling the spread of disease. A study described an outbreak of giardiasis that occurred at a swimming pool in 1985 [28]. When the water was tested at the venue there was no chlorine present in the water, which emphasises the need to have appropriate levels of chlorine, or other disinfectants, to control the spread of disease. In 2010, the native Icelandic horse population was affected by a Strangles (respiratory disease) epidemic. A subsequent epidemiological investigation revealed that a WT used at one of the main rehabilitation and training yards in Iceland was a critical trigger for the epidemic [29]. The water in this WT did not contain any disinfectant or chemicals and was only changed on a once or twice weekly basis, providing optimum conditions for disease transmission. Our study indicated that skin and fungal conditions were frequently reported adverse effects after WT usage, which supports the need for disinfection to avoid the spread or exacerbation of these conditions.

A previous study comparing the heart rates of horses over the course of the first four WT sessions showed that horses that were started without sedation exhibited higher peak heart rates (over the course of the four sessions) than horses that were sedated for the first session only [23]. Thirty-five percent of the respondents indicated that they used sedation and calmers when habituating their cases to the WT. Sedatives and tranquilisers are frequently administered to horses to decrease their responsiveness to external stimuli when horses are exposed to stressful situations and/or new environments [30]. Acepromazine (a phenothiazine tranquiliser) is recognised for its ability to reduce anxiety whilst maintaining avoidance behaviours and romifidine and detomidine (both nonopioid sedative-analgesics) cause horses to become indifferent to their surroundings, muscle relaxation and a decrease in heart rate [31-32]. Previous work has shown that these drugs can reduce anxiety for non-invasive procedures and

346 when given in combination can allow for lower doses to be used which may be safer and more
347 effective than giving a larger dose of a single drug [30, 32]. Our results showed that
348 acepromazine, romifidine and detomidine or combinations of these were most frequently used.
349
350 Numerous human [33-35] and equine [36-39] studies have shown that overground locomotion
351 is different to dry treadmill locomotion, and therefore it should be expected that a horse will
352 need a certain amount of time to be able to carry out WT exercise without signs of anxiety and
353 with a stable gait [39-40]. A study of habituation to locomotion on a dry treadmill has shown
354 that at least three 5 minute sessions are required for trot kinematics to stabilise and in walk it
355 could take up to 10 sessions for kinematic patterns to stabilise [40]. Physiological [23] and
356 stride variables [6] have been described in walking horses habituating to WT exercise but there
357 are no published studies describing these variables in trotting horses on a WT. Further studies
358 are required to describe how long it takes for horses gait variables to reach a steady state in trot
359 on a WT, and for how they can be maintained in one exercise session.
360
361 It is interesting to note that 60% of our horse specific questionnaires were for training and 40%
362 for rehabilitation. In contrast, at two local canine hydrotherapy centres 70% of their WT
363 sessions are for rehabilitation and 30% for fitness training although it should be acknowledged
364 that they are part of veterinary clinics which give priority to their clinical cases requiring
365 rehabilitation over external cases wanting fitness training. This may be because horses are
366 frequently required to be athletes, where training is a required component of management,
367 whereas the canine population may have less athletic requirement. There are a few studies
368 indicating short term kinematic [5-9] and physiological [6, 23, 25-26] effects of water treadmill
369 exercise but there is a paucity of information on the long-term effect of WT exercise for training
370 purposes, so research efforts are warranted in this area.

The speeds used for training and rehabilitation sessions did not appear to vary widely; however mean walk speed was significantly greater during rehabilitation compared to training sessions. We also observed that one venue used higher speeds, including trot, than the rest of the contributing venues. All other venues using WT exercise as part of a rehabilitation programme only walked the horses. Nankervis et al. [2] highlighted that walking through water increases the drag force experienced which is why a comfortable walk speed is approximately 50% lower than walking on a land treadmill or overground; the same is applicable to the human [41]. It is likely that lower walking speeds would be beneficial during rehabilitation sessions to reduce the strain on the injured structures. Nankervis et al. [2] also indicated that trotting in water could force the horse to extend their thoracolumbar region; this would be considered undesirable in horses rehabilitating from back or hindlimb injury. Trotting potentially has a very limited place in WT rehabilitation sessions for specific conditions. A longitudinal study following horses over time recovering from a variety of conditions using WTs as part of their programme is warranted.

It appeared that water depths used for training and rehabilitation sessions did not vary widely, however deeper water (carpus/hock level and above) was used more frequently for training sessions and lower depths (mid-cannon level and below) were favoured for rehabilitation sessions. Seventy-five percent of the cases rehabilitating from soft tissue injury were exercised in water above the affected structure. For the horses rehabilitating from bone pathology in 67% of the cases they were in water above the affected joint. It has previously been suggested that for horses suffering from carpal bone pathology deeper water (above the affected joint) would be beneficial as the limbs would be subjected to lower vertical ground reaction forces [3]. Deep water (level with the abdomen) may be beneficial for horses suffering from specific distal limb

injury where decreased weight bearing exercise was recommended. A number of studies [6, 23, 25, 42] have indicated that increasing water depth does not appear to increase workload, as confirmed by physiological and biochemical variables. However WT exercise could be used to maintain a certain level of fitness with reduced joint loading with the potential to reduce injury risk. It appears that current equine studies [4, 7-8, 25-26] have investigated/included greater water depths than currently used in practice suggesting that further work is warranted in shallow water, i.e. hock depth and below.

The duration for training and rehabilitation sessions did not appear to vary widely; however the mean duration of a training session was significantly longer than a rehabilitation session. It was noted that the same venue that used faster walk and trot speeds also appeared to have longer sessions for both training and rehabilitation than the other contributing venues. One study [26] indicated that horses did not show signs of fatigue as the duration of a WT session increased. However for each trial the horses were exercised at the same speed and in deep water (above the shoulder). The workload may be different if horses were exercised at different speeds and altering water depths within one exercise session. Further work is required to determine how the duration of a session in different water depths affects the consistency of stride variables and the long term performance in the equine athlete. There were no previous comments on how session duration affects the return to work in an injured horse. Typically in canine WT exercise, rehabilitation sessions tend to be half the time of a training session (Handley-Howard, pers. comm.).

We noted significant differences between training and rehabilitation sessions with training sessions being longer, and using slower walk speeds and deeper water than rehabilitation sessions. This supports clinical impressions/experiences as it could be contraindicated to work

421 a horse recovering from injury on a WT for long periods of time. Faster walk speeds, that also
422 retain correct kinematic patterns, are only possible at lower water depths as there will be less
423 drag effect. Walking and trotting in water requires more intense muscle activity and can
424 contribute to increasing muscle mass/development [10] and cardiovascular capacity [25];
425 which could be a potential explanation for the selection of deeper water levels for training
426 sessions.
427
428 Numerous equine studies indicated that cross-training (different types of exercise) decreases
429 the risk of injury to the sport horse [43-45]. Our results indicated that on average horses could
430 have one WT session per day; three respondents indicated that a single horse, that was present
431 for therapy or fitness livery, could have up to two WT sessions a day. To our knowledge there
432 are no studies describing how multiple WT sessions within one week affect the horses'
433 kinematics over land and therefore a longitudinal study monitoring horses after individual
434 multiple WT sessions per week is warranted.
435
436 The current study showed that WT were used as part of rehabilitation programmes of horses
437 suffering from musculoskeletal conditions; this in in accordance with human [46-47] and
438 canine [48-49] studies. Canine studies suggested that WT exercise for the rehabilitation of
439 musculoskeletal injury should be part of a treatment programme and not used in isolation. One
440 equine study had directly compared the effect of WT compared to land treadmill exercise on
441 postural sway in horses with surgically induced osteoarthritis [3]. The results indicated that
442 WT exercise reduced postural sway compared to land treadmill exercise which was attributed
443 to WT exercise activating the motor neuron pool for the muscles that stabilise the limbs,
444 therefore improving balance and postural stability. However there is no scientific evidence to

support the current protocols that are being used and to our knowledge this is the first study describing what WT users are doing.

The owner questionnaire showed that horses from all disciplines use WTs; however dressage and eventers were the most frequent users. Over half of the respondents had experience of their horse using a WT for training purposes. This could be related to recent reports of high-profile horses using WTs as part of their regular training regimes. A small percentage of owners continued using WTs as part of their horses' regular training programme after they were successfully rehabilitated from injury. The main reason for using a specific venue was due to a recommendation and the distance from their home. This would be especially important if their horse was an 'outpatient' and therefore a venue closer to home would make logistics much easier for the owner. Over three quarters of the respondents reported that after WT exercise there was improved performance and improved coordination, strength and muscle development; this is in accordance with what has been reported in dogs [48-49]. However it was not asked how the owner perceived the improvement in performance. Potential reasons could include: more wins, better dressage scores, faster clear rounds in jump-offs and the ability to train for longer before fatiguing.

4.1 Limitations

As a questionnaire-based study, the results were based on respondents' interpretation of the question. To minimise this effect care was taken in the choice of wording used in questions to achieve ease of understanding which was tested in the pilot study. There was a heavy bias in the number of respondents from the UK, so the results have been interpreted in the context of this UK bias. Our sample population was also heavily biased towards venues that had Activomed and Aqua Icelander machines, as these particular companies assisted with

questionnaire distribution. However, many of these clients were also access via other routes, so the degree of bias may have been more limited than the initial impression. The client feedback questionnaire was primarily distributed to current WT users, as it was more difficult to get previous WT users to complete questionnaires even if they had had negative experiences, so it is likely that we missed a number of negative issues that weren't reported by previous WT users that had stopped using the system. Current use of a WT is obviously biased by access, cost, impression and peer pressure among factors so answers should be viewed in this context, but this was a descriptive study and we were not seeking to identify risk factors or design protocols for specific outcomes at this stage. This baseline information could be used to develop further more targeted investigations in the future.

5. Conclusions

This study provides novel information on current equine WT usage patterns and protocols used for habituation, training and rehabilitation. WT's were mainly used for training (60% of the cases) and for rehabilitation of numerous musculoskeletal conditions. Habituation protocols were similar between venues but significant variations were recorded in training and rehabilitation protocols (speed, water depth, session duration). WT's were most frequently used for rehabilitation in horses with ligament and tendon injuries than bone pathology.

Acknowledgments

The authors are very grateful for the time spent by the participants in completing the questionnaires. Funding from the Animal Health Trust and British Equestrian Federation's UK Sport lottery funded World Class Programme.

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621

622 Table 1. Information requested in the questionnaire.

Questionnaire	**Heading**	**Specific variable**
Main	Machine specifics	Make, model, age, year of purchase; how is the horse unloaded; has it been updated/maintenance/repaired; location of the water treadmill within the venue
	Venue specifics	Type of establishment; do they own any other treadmill; how they obtain their client base; is a veterinary referral required
	Caseload overview	Total number of individual cases per week; total number of sessions per case per week; visual cues used as markers of fatigue;
	Protocols	Horse preparation prior to a session; use of sedation and/or calmers; duration, speed, water depth/temperature used for acclimatisation sessions; duration, speed, water depth/temperature used for training sessions; duration, speed, water depth/temperature used for rehabilitation sessions; what happens to the horse after the session
	Water	Type; recycling/cleaning protocols; chemical use
	Safety	Handler training; any previous accidents; head gear and protective equipment used during sessions
Horse/Case	Case details	Age; height; weight; main competitive discipline and level; competition frequency; how it's shod; average number of session per week
	Protocol	Reason/outcome; use of sedation/calmers; duration; average water depth; average speed; use of passive and/or active warm-up techniques; what was done with the horse after the session
Client/owner	Profile	Total number of horses owned; main competitive discipline; reasons for using a water treadmill; why use this specific venue; positive outcomes; negative outcomes

623

624 Table 2. Water depths most frequently used during a training session.
625

Water depth	**Total distribution n (%)**	**Distribution without 1 venue n (%)**

Hock	89 (24)	87 (38)
Above fetlock	55 (15)	7 (3)
Mid-cannon	52 (14)	13 (6)
Fetlock	47 (12)	43 (19)
Below fetlock	38 (10)	5 (2)
Below carpus	32 (9)	17 (7)
Carpus	32 (9)	31 (13)
Below hock	12 (3)	12 (5)
Above hock	7 (2)	7 (3)
Above carpus	5 (1)	5 (2)
Stifle	4 (1)	4 (2)
Forearm	1 (1)	1 (1)

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627

628 Table 3. Mean duration, in minutes, at each pace for a training session.
629

	All venues mean±sd (range)	**Without 1 venue mean±sd (range)**
Walk	20.5 ± 5.1 (5-50)	18.9 ± 4.2 (5-30)
Trot	8.8 ± 4.7 (1-24)	6.5 (1-12)
Total	23.5 ± 8.1 (5-54)	18.9 ± 4.2 (5-32)

630
631 Table 4. Desired outcomes for a training session.
632

Desired outcomes	**All venues n (%)**	**Without 1 venue n (%)**
Increased strength/conditioning/fitness	234 (62)	125 (54)
General performance improvement	217 (57)	74 (32)
Use for demonstrations	41 (11)	41 (18)
Prevention of injuries/re-injury	39 (10)	22 (10)
Improved power/strengthened hindlimb	39 (10)	39 (17)
Stronger/improved core/abdominals	33 (9)	20 (9)
Build/strengthen back muscles	16 (4)	3 (1)
Improved balance/stability	9 (2)	9 (4)
Strengthen check ligament	8 (2)	0
Improved suppleness/condition	3 (1)	1 (1)
Increased pelvic flexion	3 (1)	3 (1)
Cross training	3 (1)	0
Increase range of movement of lumbar region	3 (1)	3 (1)
Train abdominals	2 (1)	2 (1)
Giving horse an easy day	2 (1)	2 (1)
Reintroduction of work	2 (1)	2 (1)
Increase range of movement of thoracic region	2 (1)	2 (1)
Lift thorax	1 (1)	1 (1)
Improved walk quality	1 (1)	1 (1)

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634

635 Table 5. Lists all the conditions that a water treadmill has been used as part of a rehabilitation
636 programme. Specific conditions have been grouped per anatomical site or tissue type.
637

Condition	All venues n (%)	Excluding 1 venue n (%)
Suspensory and tendon injuries	**66 (41)**	**42 (39)**
Suspensory ligament Check ligament Proximal suspensory desmitis Deep digital flexor tendon injury Superficial digital flexor tendon	Torn tendon sheath Suspensory branch avulsion Collateral ligament Annular ligament injury Impar ligament damage	
Prevention/maintenance/rehabilitation of conditions	**40 (25)**	**16 (15)**
Arthritis Reintroduce to work Poor performance	Post-surgery exercise Weak core Conditioning after colic	
Back conditions	**32 (20)**	**25 (23)**
Kissing spine Sacroiliac weakness/injury Tuber coxae fracture	Torn ligament Tight through lumbar Misaligned pelvis	
Veterinary recommendation	**16 (10)**	**16 (15)**
Hindlimb injuries	**13 (8)**	**9 (8)**
Bilateral lameness Stifle injury Hock injury	Bilateral tarsal synovitis Locking stifles Hamstring injury	
Hoof injuries	**11 (7)**	**7 (7)**
Damage to hoof Bilateral navicular bone changes Bruising/inflammation to coffin bone	Changes to the coffin joint Laminitis Navicular disease	
Fractures	**8 (5)**	**8 (8)**
Hip Splint bone Pedal bone	Fracture to elbow Carpus Sesamoid bone	
Physiotherapist recommendation	**4 (3)**	**4 (4)**
Limb injuries unspecified location	**2 (1)**	**2 (2)**
Fetlock injury	Bone spavin	
General lameness	**2 (1)**	**1 (1)**
Trainer recommendation	**2 (1)**	**2 (2)**
Restricted movement in forelimbs	**1 (1)**	**1 (1)**

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642

643 Table 6. Water depth most frequently used during a rehabilitation session.
644

Water depth	All venues n (%)	Without 1 venue n (%)
Mid-cannon	40 (25)	16 (15)
Above fetlock	39 (24)	15 (14)
Below carpus	21 (13)	18 (17)
Hock	17 (11)	15 (14)
Carpus	16 (10)	16 (15)
Fetlock	13 (8)	13 (12)
Above carpus	7 (4)	5 (5)
Below fetlock	1 (1)	1 (1)
Above hock	1 (1)	1 (1)
Stifle	1 (1)	1 (1)
Forearm	1 (1)	1 (1)

645
646 Table 7. Mean duration, in minutes, for a rehabilitation session.
647

	All venues mean±sd (range)	Without 1 venue mean±sd (range)
Walk	20.6 ± 6.1 (5-40)	20.2 ± 5.6 (5-28)
Trot	7 ± 4.7 (2-18)	NA
Total	22.5 ± 7.6 (5-40)	20.2 ± 5.6 (5-28)

648
649 Table 8. Horse owner reasons for using a specific venue.
650

Reason		n (%)
Recommendations		**56 (66)**
Veterinary	Current client	
Friend	Saddler	
Complimentary therapist	Farrier	
Trainer	Physio	
Location/Distance		**44 (52)**
Rep/Review		**31 (37)**
Handlers		**28 (33)**
Specific handler	Handlers training	
Procedures employed		**11 (13)**
Safety procedures	Acclimatisation protocols	
Personal choice		**10 (12)**
Cost		**8 (9)**
The water treadmill		**5 (6)**
Make/Model	Design/Style	
Former employee/currently employed		**4 (5)**
Media		**3 (4)**
Media coverage	Popularity	
Cross training		**1 (1)**
Private training facility		**1 (1)**

651

652 Table 9. Summary of horse owner perceived improvements after water treadmill exercise.
653

Reason	**n (%)**
Improved exercise performance	**65 (78)**
Improved gait Improved general work performance Engagement hindlimb Improved straightness Improved performance Increased range of movement Improved bend suppleness Softer Improved fitness/stamina Improved strength Strengthened core	
Improved strength and muscle development	**32 (38)**
Building back muscles General muscle build up and/or increased tone Improved topline Building gluteus Even muscle tone/develop Build up muscle over hind quarters	
Improved rehabilitation results	**13 (16)**
Successful rehabilitation of injury/condition Reduced stiffness Improved soundness Less arthritic Maintenance of condition during rehabilitation	
Horse enjoys it	**2 (2)**
Cross training	**2 (2)**
Confidence in water	**1 (1)**
Reduced spookiness	**1 (1)**
Cold tight legs	**1 (1)**
Stronger tendons	**1 (1)**
Post exercise rehabilitation	**1 (1)**

654
655 Table 10. Summary of horse owner perceived negative outcomes after water treadmill
656 exercise.
657

Reason	**n (%)**
Improved horse performance past riders ability	2 (2)
Seriously injured due to water treadmill design	1 (1)
Hoof condition	1 (1)
Exacerbated injuries	1 (1)
Potentially induced hind suspensory injury due to stepping over water	1 (1)
Too intense for horses hindquarters	1 (1)
Mud fever	1 (1)

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