

## **International Survey of Equine Water Treadmills - Why, when and How?**

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1 International survey of equine water treadmills – why, when and how?  
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8

## 9 **Conflict of interest**

10 None to declare.

11

## 12 **Abstract**

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

25 water, slower walk speed and longer duration for training compared to rehabilitation;  $P \leq 0.023$  for all  
26 three variables). WT's were most frequently used for rehabilitation in horses with ligament and tendon  
27 injuries. WT habituation is important and protocols were similar between venues. WT's usage was  
28 60%:40% between training:rehabilitation with protocols varying significantly between venues.

29

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

31

### 32 **Highlights**

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

38

39

40

## 41 **1. Introduction**

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

55

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

66

67 There is some evidence that a further variable which influences the responses to WT exercise  
68 is the horse's individual movement pattern. Nankervis et al. [8], found differences in individual  
69 horse's pelvic movement patterns with increasing water depth. Of a group of competition  
70 horses believed to be sound, six out of 13 horses showed the greatest pelvic displacement in  
71 water at stifle depth whereas seven out of 13 horses showed the greatest pelvic vertical  
72 displacement at hock depth or even lower. Mooij et al. [7] observed horses over the course of  
73 10 days water walking, and found no significant changes in axial rotation, lateral bend or pelvic  
74 flexion between day 1 and day 10, implying that there was no detectable training effect on the  
75 movement of the back, despite some of the horses appearing to change their movement pattern  
76 on visual inspection. They concluded that fixed protocols may not be optimal given individual  
77 horse's patterns of pelvic movement. Both these studies show that different movement patterns  
78 may be induced by the same combination of water depth and belt speed, and so an individual  
79 horse's responses to WT exercise should be monitored both within a session and over time to  
80 ensure that the horse is responding in a way that supports the aims of the training or  
81 rehabilitation programme.

82

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

90

91 **2. Materials and Methods**

92 **2.1 Ethical Review**

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

95

96 **2.2 Questionnaire design**

97 Three questionnaires were designed:

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

105

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

110

111 **2.3 Sample population selection**

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

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

121

## 122 **2.4 Data input**

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

126

## 127 **2.5 Statistical analysis**

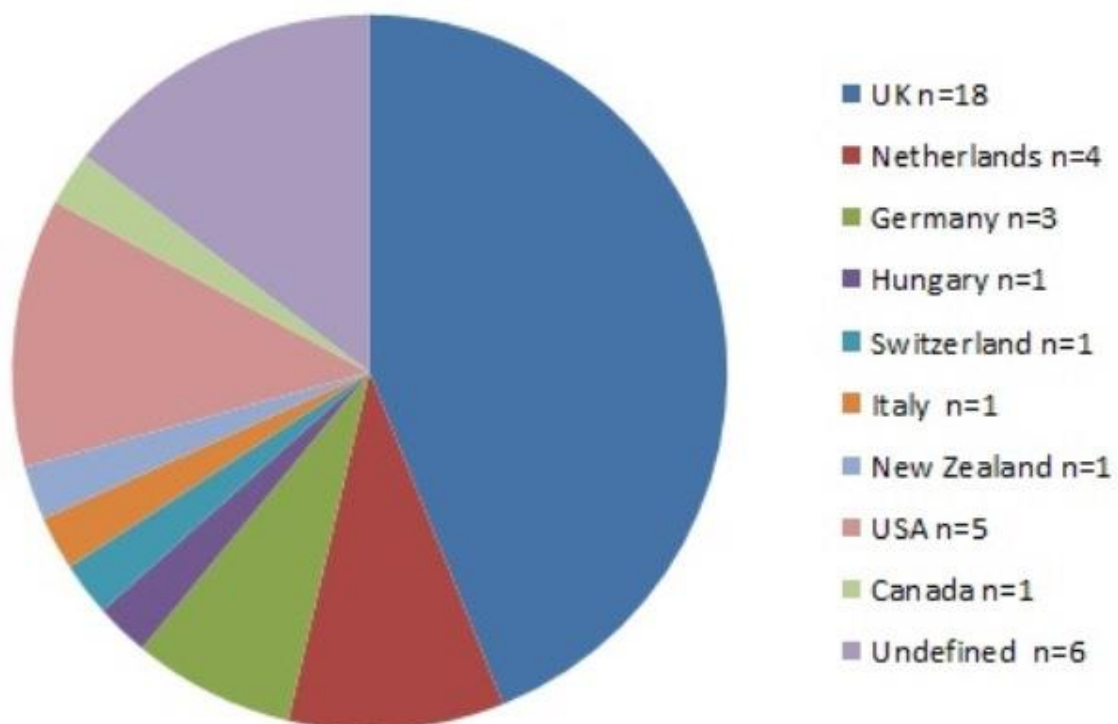
128 Descriptive analysis was undertaken for all elements of the questionnaire. A chi-squared test  
129 was used to determine if water depth (deep versus shallow: deep included hock/carpus level  
130 and above and shallow included all depths below hock and carpus) was significantly different  
131 between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

136

137 **3. Results**

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

144



145

146

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

148

149 **3.1 Questionnaire 1: Venue Information**

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



152 quiet and low activity area (71%). The Activomed machines were only found in the UK.  
153 Venues had owned their WT for an average of 60 months (range: 0.5-300). In 92% of the  
154 venues the horse was unloaded going forwards. In 83% of the venues the handlers were trained  
155 in-house and horses were held from both sides in 63% of the venues. Thirty-six respondents  
156 used fresh water and five used salt water (four in the UK and one in North America). Twenty-  
157 one venues changed the water after five or more single horse exercise sessions, five venues  
158 changed the water after every session and three venues never changed the water. Venues that  
159 recycled the water used filtration systems (including sand and carbon systems) (71%),  
160 ultraviolet (UV) radiation units (52%) or a water purifier (5%). Venues that chemically cleaned  
161 their water most frequently used sodium hypochlorite (75%) and chlorine (50%). Fourteen of  
162 the respondents indicated they controlled the water temperature (mean: 13°C/55°F; range: 4-  
163 24°C/39-75°F); reasons given for controlling the water temperature included veterinary  
164 condition, standard protocol, previous horse WT experience and to prevent microbial growth.  
165  
166 Fourteen venues sedated and/or used calmers. Reasons included: difficult horse (24%),  
167 habituation session (22%), owner request (8%), when it was merited (3%) or if the horse was  
168 injured (3%). Injection was the most frequently used technique (43%) followed by oral paste  
169 (7%) and injection and tablet (7%); six of the venues did not report their technique. Six venues  
170 did not specify what was used as sedation. Romifidine was most frequently used (29%),  
171 followed by detomidine (14%), acepromazine (7%) and a combination of acepromazine and  
172 romifidine (7%).  
173  
174 All participating venues indicated that session type (habituation, training or rehabilitation),  
175 veterinary condition, horse fitness/previous experience/age/weight all significantly influenced  
176 the session duration, water depth and speed used for an individual horse. An individual horse

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

179

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

186

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

198

### 199 **3.2 Questionnaire 2: Individual Horse Information**

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

202 (20%)) and one rehabilitation centre in the Netherlands (5%). Seventy-three percent of these  
203 questionnaires were collected retrospectively by one of the authors (JBT) from four UK venues  
204 (two colleges and two rehabilitation centres).

205

### 206 **3.2.1 Habituation**

207 Seven of the venues took between two and three sessions of ‘habituation’ to accustom the horse  
208 to the speed and depth of water required for exercise; one venue did not carry out any  
209 habituation sessions during the data collection period. Habituation sessions typically ranged  
210 from 10-30min in duration with the water depth slowly increasing to the level of the hock by  
211 the end of the second or third session depending on the venue. The average walk speed was  
212 1.6m/s (range: 0.7-2.8). One venue trotted their cases during habituation with a mean speed of  
213 4.4m/s (range: 3.9-4.9). Seventy percent of the cases were sedated for first time only (n=21)  
214 and 30% of the cases were also sedated for the second session.

215

### 216 **3.2.2 Training**

217 Sixty percent of the case-specific responses were for training protocols, mainly sports horses  
218 (32% dressage, 16% eventing and 8% show jumping). Hock depth water was most frequently  
219 used (24%) (Table 2), average walk speed was 1.6m/s (range: 0.7-3) and average trot speed  
220 was 4.4m/s (range: 3-5). The mean total session duration was 23.5min (range: 5-54) (Table 3).  
221 The two main outcomes of a session were an impression of increased strength/condition/fitness  
222 (62%) and an improvement in general performance (57%) as perceived by the owner/rider  
223 (Table 4).

224

### 225 **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

#### 246 **4. Discussion**

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

251

252 The results showed that the average age of a WT was 60 months, with the minimum age being  
253 0.5 months and maximum age being 300 months. This suggests, and supports anecdotal reports,  
254 that WT production and usage may have increased in the last five years, and supports the  
255 subjective impression of recent increased use in equine rehabilitation and training programmes.

256 Our study indicated that the three most frequently owned machine types were FMBs  
257 Activomed, Formax Aqua Icelander and the Horsegym Aquatrainer. Obviously these results  
258 have a level of bias, in that we tried to distribute questionnaires through various manufacturers,  
259 and because most data was collected from the UK. However, we were relatively unsuccessful  
260 in this distribution in comparison with other methods of access to venues and individuals, so  
261 the level of bias is likely to have been limited. Activomed machines are marketed and sold by  
262 a company that also supply and sell a number of equine therapy systems and equipment. A  
263 number of UK International riders' use their products which could explain why they are the  
264 most common machine in the study as the majority of the respondents were based in the UK.  
265 The Formax machines are manufactured by a small company based in Iceland but have clients  
266 based in numerous countries. The Horsegym machines are manufactured in Germany but their  
267 client list covers numerous elite level riders, from all disciplines, from a number of European  
268 countries and in the United States of America. This might explain why they are the third most  
269 frequently owned machine type.

270

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

279

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

290

291 In human studies of WT exercise, water temperature ranged from 28 to 32°C [14-20] and in  
292 canine studies the temperature ranged from 30 to 35°C [21-22]. In contrast in equine studies  
293 the water temperature ranged from 13 to 22°C [1, 11, 23-26]. The temperature ranges reported  
294 by the respondents in the current study have a much lower minimum temperature (4°C). The  
295 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

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

334

335 A previous study comparing the heart rates of horses over the course of the first four WT  
336 sessions showed that horses that were started without sedation exhibited higher peak heart rates  
337 (over the course of the four sessions) than horses that were sedated for the first session only  
338 [23]. Thirty-five percent of the respondents indicated that they used sedation and calmers when  
339 habituating their cases to the WT. Sedatives and tranquilisers are frequently administered to  
340 horses to decrease their responsiveness to external stimuli when horses are exposed to stressful  
341 situations and/or new environments [30]. Acepromazine (a phenothiazine tranquiliser) is  
342 recognised for its ability to reduce anxiety whilst maintaining avoidance behaviours and  
343 romifidine and detomidine (both nonopioid sedative-analgesics) cause horses to become  
344 indifferent to their surroundings, muscle relaxation and a decrease in heart rate [31-32].  
345 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.

371

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

386

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

396 injury where decreased weight bearing exercise was recommended. A number of studies [6,  
397 23, 25, 42] have indicated that increasing water depth does not appear to increase workload, as  
398 confirmed by physiological and biochemical variables. However WT exercise could be used to  
399 maintain a certain level of fitness with reduced joint loading with the potential to reduce injury  
400 risk. It appears that current equine studies [4, 7-8, 25-26] have investigated/included greater  
401 water depths than currently used in practice suggesting that further work is warranted in  
402 shallow water, i.e. hock depth and below.

403

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

417

418 We noted significant differences between training and rehabilitation sessions with training  
419 sessions being longer, and using slower walk speeds and deeper water than rehabilitation  
420 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 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

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

447

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

462

#### 463 **4.1 Limitations**

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

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

480

481 **5. Conclusions**

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

488

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493

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621

622 Table 1. Information requested in the questionnaire.

<b>Questionnaire</b>	<b>Heading</b>	<b>Specific variable</b>
Main	Machine specifics	Make, model, age, year of purchase; how is the horse unloaded; has it been updated/maintenance/repared; 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

<b>Water depth</b>	<b>Total distribution n (%)</b>	<b>Distribution without 1 venue n (%)</b>
--------------------	---------------------------------	---

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)

626  
627

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

	<b>All venues mean±sd (range)</b>	<b>Without 1 venue mean±sd (range)</b>
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 Table 4. Desired outcomes for a training session.  
 631  
 632

<b>Desired outcomes</b>	<b>All venues n (%)</b>	<b>Without 1 venue n (%)</b>
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)

633  
 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

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

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 642



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

<b>Water depth</b>	<b>All venues n (%)</b>	<b>Without 1 venue n (%)</b>
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 Table 7. Mean duration, in minutes, for a rehabilitation session.  
646  
647

	<b>All venues mean±sd (range)</b>	<b>Without 1 venue mean±sd (range)</b>
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 Table 8. Horse owner reasons for using a specific venue.  
649  
650

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

651

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

<b>Reason</b>	<b>n (%)</b>
<b>Improved exercise performance</b>	<b>65 (78)</b>
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
<b>Improved strength and muscle development</b>	<b>32 (38)</b>
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
<b>Improved rehabilitation results</b>	<b>13 (16)</b>
Successful rehabilitation of injury/condition Reduced stiffness Improved soundness	Less arthritic Maintenance of condition during rehabilitation
<b>Horse enjoys it</b>	<b>2 (2)</b>
<b>Cross training</b>	<b>2 (2)</b>
<b>Confidence in water</b>	<b>1 (1)</b>
<b>Reduced spookiness</b>	<b>1 (1)</b>
<b>Cold tight legs</b>	<b>1 (1)</b>
<b>Stronger tendons</b>	<b>1 (1)</b>
<b>Post exercise rehabilitation</b>	<b>1 (1)</b>

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

<b>Reason</b>	<b>n (%)</b>
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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660