APMB - Atti della Accademia Peloritana dei Pericolanti
Classe di Scienze Medico Biologiche
Vol. 107(2) 2019

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

Scholarly Dialogs SD3(1-11)

Exercise in the water: should we incorporate it into training and rehabilitation programs for the sport horse?

[1,2]Ana Muñoz, [1]Mireya Becero, [2,3]Aritz Saitua, [3]David Argüelles, [1,3]Antonia Sánchez de Medina, [2]Cristina Castejón-Riber

[1]Department of Animal Medicine and Surgery, School of Veterinary Medicine, University of Córdoba, Spain; [2]Equine Sport Medicine Centre CEMEDE, School of Veterinary Medicine, University of Córdoba, Spain; [3]Veterinary Teaching Hospital, School of Veterinary Medicine, University of Córdoba, Spain

Abstract

In recent years, many trainers have considered the exercise in water as a tool to be incorporated into training programs for sport horses. Additionally, exercise in water could be used for rehabilitation of musculoskeletal and neurological injuries. This use derives from the application of the physical properties of the water, such as viscosity (greater muscular work compared to terrestrial locomotion), buoyancy (reduced load on the axial skeleton) and hydrostatic pressure (circumferential compression that reduces edema and inflammation). There are several devices for water exercise, such as swimming pools (full flotation), water treadmill WT (semi-flotation) and aquatic walkers. The cardiovascular, metabolic, muscular and locomotor responses differ significantly during exercise in a swimming pool compared to a WT. Exercise on a WT is of submaximal intensity, as shown by the response of heart rate and lactate concentration. Cardiovascular and metabolic response to a terrestrial treadmill exercise tests does not change after a training program on a WT. Fiber muscle composition of the gluteus medius muscle does not appear to be affected by WT training. However, our research team has found that there are significant increases in total power and its distribution in the three body axes (dorsoventral, longitudinal, mediolateral), which could have a significant impact on dressage, jumping and three-day-event horses. Further, exercise on a WT might promote a normal locomotor pattern after an injury, increasing the range of movement, enhancing proprioception, and reducing inflammation, with a lower limb load. Its use can be recommended for chronic tendinitis and desmitis and particularly for chronic osteoarthritis.

Key Words: Exercise; Horses; Rehabilitation; Training Water

Introducing Member: Adriana Ferlazzo

Corresponding Author: Ana Muñoz - pv1mujua@uco.es

Introduction

In the last years, exercise is water has become a tool to be introduced into training programs for sport horses, because of the belief that it might improve cardiovascular and muscle capacities while reducing the load on the axial skeleton (1). In addition, exercise in water might be used also for rehabilitation of horses with locomotor or neurological disorders (2-5). Other possible benefits of this type of exercise are in study at this moment, with a pilot research showing that it could improve insulin-glucose metabolism (6). This research investigated the potential use of

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

water exercise in horses with equine metabolic syndrome, insulin resistance, particularly if there is a concern for endocrinophatic laminitis.

Despite the increasing popularity of this modality of exercise in training and rehabilitation centers worldwide, there are little scientific evidences confirming their effects yet.

Systems available for exercise in water in the horse

The most known systems to exercise a horse in water are the aqua walkers, the swimming pools and the water treadmills (5,7). Aqua walkers are walkers fitted within a circular pool with a consistent depth of water. They have a fixed diameter, which determines the number of horses that can be exercised at the same time. There is not a complete buoyance in this system, and it is designed for a specific water depth. Swimming pools have been the most used system to train and rehabilitate horses up to now (1,5,7-8). However, before using the swimming pool, some considerations should be considered. Horses are not natural swimmers, and they use the forelimbs to maintain balance and the hindquarters for propulsion. This function of the pelvic limbs leads to exaggerated propulsion movements, with extreme range of motion, that might be contraindicated for sacroiliac, pelvis, hock and fetlock joints. In addition, the horse swims in a lordotic position, with cervical, thoracolumbar and pelvic extension and the use of neuromuscular groups is different compared to terrestrial locomotion (5,7,9).

In the last years, different types of water treadmills (WTs) have been commercialized. The current article will focus on this system.

Physical properties of the water

Exercise in water is based on the physical properties of water, which will be described briefly. For more information, reviews as those performed by Muñoz et al. (5), King (7) and Nankervis et al. (9) are recommended.

The main physical properties of the water with applications in the field of training and rehabilitation are buoyancy, viscosity and hydrostatic pressure. In addition, the WT allows a strict control of velocity and the depth of the water.

Buoyancy is the force of opposite direction to the force of gravity, according to the Archimedes' principle. Therefore, a body immersed in the water appears to have less weight, and this reduction of weight is inversely correlated with the depth of the water (2,5,7,9-10). Because of the buoyancy, a horse can be exercised on the WT with a reduced limb load. This is an important aspect in rehabilitation, because the injured limb can be exercised but the load supported would

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

be lesser compared to terrestrial locomotion, as has been recently demonstrated (11) and in addition, as the horse improves, the depth of the water can be reduced in order to increase progressively the load supported by the limb.

Viscosity is the resistance of a fluid to flow. Water has 12 times more viscosity compared to air, and consequently, a greater effort is required to move in water, leading to greater muscle activation, muscle strength, motor control and joint stability (2-3,5). This property is really important for training the sport horse, in order to improve strength, but also in injured horses. Most of the horses with locomotor disorders experienced a reduction in their training intensity and consequently, an exercise of great power/strength might lead to fatigue and muscle injury (9,12).

Hydrostatic pressure is regulated by Pascal's low, which states that a fluid exerts a pressure over all surfaces of an immersed body. Therefore, exercise in water causes a circumferential compression of equal magnitude of extravascular hydrostatic pressure, promoting venous return and lymphatic drainage. It could help to decrease soft tissue swelling at the same time that improves neuromuscular function, as a consequence of the stimulation of skin surface sensory nerves and joint mechanoreceptors and the enhancement muscle spindle activity (2-3,5,7).

Use of the water treadmill for training of sport horses

Cardiovascular and metabolic response. Changes in muscle histochemistry and biochemistry

In order to assess whether this type of exercise should be included into a training program for sport horses, firstly we need to know the cardiovascular and metabolic response during and after a WT session. We have studied 6 adult horses with different fitness level, of both sexes, acclimatized to WT exercise. The animals were subjected to WT sessions of 40 min (5 min filling + 30 min at each water depth+5 min water discharge), at walk, with velocities between 5.5-6 km/h. Horses were exercised on 4 occasions in a randomized study (13), without water (control) and with the water at the level of fetlock, hock and stifle. Mean heart rates (HR) of 66, 71, 82 and 81 bpm/ and blood lactate (LA) accumulation of 1.01, 1.05, 1.05 and 1.11 mmol/l were found in the control, and with the water at the level of the fetlock, hock and stifle, respectively (13). These data indicate that exercise on a WT is an aerobic submaximal intensity work. From a cardiovascular and a metabolic point of view, consequently, it does not represent a challenge for a sport horse. That leads to the question that if this type of exercise would result in fitness improvement.

Several studies have tried to answer this question. Borgia et al. (14) carried out a standardized

 ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

exercise test on a land treadmill before and after 4 weeks of WT training. The training program used in the paper of Borgia et al. (14) was this recommended by the manufacturer for rehabilitation of tendinitis (bowed tendon) and consisted in 5 sessions/week, with a duration of 5 min the 1stweek, 10 min the 2ndweek, 15 min the 3rd week and 20 min the 4thweek, at the level of the stifle/abdomen, at a speed of 2 m/s (7 km/h). These authors, during the standardized exercise test on a land treadmill calculated two markers of performance: V200 (velocity at a HR of 200 bpm) and V4 (velocity at a blood LA concentration of 4 mmol/l). The expected response to the training, indicating an improvement in fitness, would be an increase in V200 and V4 (15-16). Further, they drawn biopsies from the gluteus and superficial digital flexor muscles in order to measure substrate and metabolite concentrations (glycogen, ATP, glucose-6P and LA) and enzyme activities (CS, citrate synthase, a marker of muscle aerobic metabolism; Krebs cycle; HAD, 3-OH-acyl coenzyme A, a marker of lipid metabolism; LDH, lactate dehydrogenase, a marker of muscle anaerobic metabolism). HR, LA, V200 and V4 did not change with WT training. No differences in muscle concentrations of substrates and metabolites at rest were not found neither. Consequently, the study of Borgia et al. (14) concluded that 4-weeks of WT training did neither affect resting muscle composition nor muscle oxidative capacity.

The same group of authors (17) compared some years later the effect of the same training program on land treadmill and on a WT. They evaluated the response to a training with a standardized exercise test on the land treadmill and they took muscle biopsies in order to perform muscle histochemistry and biochemistry. Training program consisted in sessions performed 5 days/week, with the following duration: 1stweek (16-20 min), 2ndweek (21-25 min), 3rdweek (26-30 min), 4thweek (31-35 min), 5thweek (36-40 min) and 6thweek (40 min). On the WT, depth was fixed at the level of the olecranon and the velocity at 1.5 m/s. There were no significant changes in the percentage of muscle fibers type I, IIA and IIB, nor after land treadmill training neither after WT training (17).

Consequently, the studies performed until now have demonstrated that WT is an aerobic low intensity exercise. Therefore, this type of exercise could be considered an ideal low-impact activity, safe for a fragile population (geriatric horses, laminitic animals, locomotor disorders…) from cardiovascular and metabolic points of view.

In opinion of the authors’ there are two aspects that deserve investigation. We would need to evaluate the use of the type of exercise in the capacity of recovery of the horse after exercise and also, its possible use as a tapering method. Our research team is working now in these potential application of the WT

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

Stride kinematic and kinetic changes

Besides considering the cardiovascular and metabolic adaptations to a training program, it is of vital importance to know the locomotor differences between WT locomotion and terrestrial locomotion. Some papers have described the changes in the stride length and frequency at different depths (13,18-21) and in the range of motion of the distal joints of the limbs (18). Our research team has investigated the kinematic and kinetic changes in horses exercised on a WT using a triaxial accelerometer (Equimetrix®), fixed on two different locations: in the caudal part of the sternum, between the right and left pectoralis ascendens muscles at the level of the girth (near the body center of gravity) and in the midline of the sacrum region. It is accepted that the location in the sternum provides more sensitive information about the dorsoventral pattern of acceleration of the forelimbs whereas the location in the sacrum provides more sensitive information about the hindlimbs (22).

We measured two groups of parameters: stride energetic parameters and coordination parameters. Stride energetic parameters include total power, dorsoventral, longitudinal, and mediolateral power and dorsoventral displacement. Power results from the multiplication of the strength by the velocity. Coordination parameters include regularity and symmetry. Stride regularity measures the acceleration pattern similarity of successive strides in a period of time and stride symmetry measures the similarities between left and right acceleration patterns (22).

Firstly, we would like to know which accelerometric changes happened during exercise sessions on a WT at different depths (12,13,19,21). With the accelerometer fixed on the sacrum, total power values of 6.661 W/kg (without water), 7.972 W/kg (water at the level of the fetlock) and 9.011 W/kg (water at the level of the hock) were found at velocities of 6 km/h. This greater total power was redistributed mainly in two body axes: dorsoventral and mediolateral, with smaller changes in the longitudinal axis. In this way, dorsoventral power increased from 2.339 W/kg (without water) to 3.428 W/kg (water at the level of the hock) and mediolateral power increased from 1.822 W/kg (without water) to 2.939 W/kg (water at the level of the hock). An interesting result was the greater dorsoventral displacement of the center of gravity with the depth of the water, measured with the accelerometer fixed on the sternum area (3.056 cm without water; 3.500 cm with the water at the level of the fetlock; 3.944 cm with the water at the level of the hock).

However, TP decreased with the water at the level of the stifle (5.800 W/kg), because horses were not able to maintain the same velocity that at the other water levels (12,21). We did not know whether the significant reduction in total power with the water at the level of the stifle compared to hock could have been associated with a greater buoyancy or with a reduced velocity or a

 ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

combination of both. For that reason and in order to elucidate which was the main explanation for our results, another group of 6 horses were subjected to the same WT exercise protocol, but the sessions were performed at a lower velocity (5 km/h). We found that there were not significant differences in total power during the exercise at the level of the hock and stifle (9.514 and 9.444 W/kg, respectively) (21).

Total power is a marker of the total strength/force that a horse can produce. This total power might be distributed towards the three body axes according to the requirements of the horse during the execution of defined types of exercise. Thus, an endurance or a racehorse needs to distribute most of the total power towards the longitudinal axis, in order to increase velocity. In dressage horses, it has been demonstrated that the horses with a larger dorsoventral displacement and a greater longitudinal power get higher scores by the judges, because of the impression of greater elasticity and good propulsion. Similarly, at walk, higher values for stride regularity, symmetry, dorsoventral power, dorsoventral displacement resulted in better scores (23). Similarly, a greater dorsoventral displacement of the center of gravity might be a good characteristic for a jumper or an eventer horse.

The next step in our investigations were to evaluate if, these changes that occurred during an exercise session on the WT, were maintained later during terrestrial locomotion. In order to achieve this goal, 5 horses were trained during 4 weeks on the WT. Training consisted in daily exercise on the WT, 10 min with the water at the level of the hock, at a velocity of 6 km/h, followed by other 10 min with the water at the level of the stifle, at a velocity of 5 km/h. The horses were assessed by accelerometry in a track, at walk and at trot, with the accelerometer fixed on the sternum. The controls were made before training and after 2 and 4 weeks of training. At the walk, total power increased after 2 weeks of training (3.9 W/kg vs 4.3 W/kg). This increase leads to significant increases in dorsoventral power (0.7 W/kg vs. 0.950 W/kg). Dorsoventral displacement of the center of gravity increased from 3.0 to 4.5 cm. Changes induced by training were more evident when accelerometry was performed at trot in the track. Velocity increased with training (3.014 m/s before training, 3.270 m/s after 4 weeks of training), and this increase was reached by means of longer strides (stride length: 2.090 m before training; 2.185 m after 4 weeks of training). Stride frequency was not modified. Stride regularity and symmetry were not changed by training neither. A marked increase in total power was found (26.25 W/kg before training and 32.65 and 36.25 W/kg after 2 and 4 weeks of WT training respectively). This increase affected the three body axes, with significant increases in dorsoventral power (13.35 W/kg before vs. 16.90 W/kg after training), longitudinal power (6.4 W/kg before vs. 9.35 W/kg

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

after training) and mediolateral power (8.3 W/kg before vs. 13.35 W/kg after training).Our results appear to indicate that training on a WT results in increased total power, which might be redirected to any or several of the body axes, depending on the exercise surface, gait or type of exercise carried out by the horse. However, we should keep in mind that our result is a preliminary study performed in 5 horses. It would be necessary to carry out this experiment on a higher number of horses, as well as to integrate this type of exercise into a usual terrestrial training. As long as we do not have more precise results on this subject, and based on our data, we believe that it would be interesting to incorporate training on a WT within the training program for dressage, show jumping or three-day-event. For other types of competitions, such as endurance, it should be evaluated with additional researches.
Unfortunately, in our study, muscle development was not measured. However, we have found significant increase in muscle size after WT treadmill in horses with disuse atrophy associated with chronic lameness (24).

Use of the water treadmill for rehabilitation of sport horses

Rehabilitation of superficial digital flexor tendon, its accessory ligament and suspensory ligament.

Currently, there are not specific indications for exercising on a WT a horse with acute superficial digital flexor tendinitis. It has been suggested that the normal pendulum of the limb might be affected by the depth of the water and we should take into account that the protraction of the distal limb is mainly passive due to the release of the elastic energy stored in this tendon, and in a lesser degree in the suspensory ligament (5,9-10,25). On the contrary, the exercise on a WT is recommended in chronic tendinitis, with the water at the level of the abdomen or stifle in order to increase buoyancy and to limit the load supported by the affected limb (5).
Special care should be put in the rehabilitation of the proximal suspensory desmitis of the hindlimbs, because of the increased retraction of the limb in the treadmill (both in land and water treadmill) (5,25-26). In addition, and because exercise on the WT with the water at the levels of the hock and stifle, results in a significant increase in flexion of the distal joints of the hindlimbs (18), proximal suspensory desmitis might aggravate. However, water at a deeper depth (abdomen or even more), together with a reduction in velocity, might reduce the load on the suspensory ligament during the stance phase of the stride. Further, exercise on the WT might increase the drag force on the hindlimb with the potential of increased muscle development (5).
The rider influences the kinematic of the limbs, leading to higher values of extension and range of

 ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

motion of the fetlock, mainly but not exclusively in the forelimbs. Therefore, the exercise on a WT before starting riding exercises in horses with fetlock, superficial digital flexor tendon and suspensory ligament injuries is highly recommended (5).

Rehabilitation of the deep digital tendon and its accessory ligament

Because the increased retraction during the stance phase on a treadmill (both on land and water treadmill) probably result in a greater stretch on these structures, the use of treadmills for rehabilitation of the deep digital tendon and its accessory ligament might not be recommended (9).

Rehabilitation of the back injuries

Some authors have revealed that horses, according to their conformation, can adopt different back kinematic strategies in order to adapt to the depth of the water (5,27-28). The kinematic of the back depends on the position of the head and neck and on the kinematic changes on the limbs. In shallow water, the horse keeps the head and neck low, and a slight cranial thoracic extension can occur (28). When the water is deeper, the horse tends to raise the neck, achieving a greater cervical and cranial thoracic extension. Additionally, the greater protraction of the hindlimbs together with the increased flexion of the distal joints of the hindlimbs, cause a tension effect on the back, according to the theory of the bow and string that explains the kinematic of the equine back (5). Because of that, there is an increase in the range of motion at the level of L3 due to an increase in flexion. The range of motion in T18 appears to show an intermediate pattern between the extension of T13 and the flexion of L3 (28). Therefore, especial caution should be taken with the exercise on the WT in horses with injuries cranial to T13, particularly with deep water, due to the cranial thoracic extension (5,27-28).

Rehabilitation of joint disease

Exercise on a WT, as stated before, results in a great increase in the range of motion of the distal joints of the limbs, achieving the maximal values at different water depths for each joint (18). Although joint extension increases, the most marked increase is found in flexion. Because of this fact, exercise on a WT is not indicated during acute joint disease. On the other hand, there are scientific evidences that demonstrates the usefulness of this type of exercise in the rehabilitation of chronic joint diseases, such as osteoarthritis. In horses, the main benefits in experimentally induced osteoarthritis are the improvement in postural control and proprioception, increase of the

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

range of motion, reduction of the compensatory biomechanical alterations secondary to the primary joint injury, increase of the activity of the stabilizing muscles of the affected joint, and a reduction histochemical changes compatible with a decrease in inflammation and fibrosis in the synovial membrane (1-2,24).

Exercise on a WT has other potential applications in equine medicine and science that deserves investigation, such as its use to manage obesity, particularly in cases of endocrinopathic laminitis or osteoarthritis, in neurological disorders or in order to strengthen abdominal muscles after colic surgery.

Conclusions

In conclusion, the exercise on a WT appears to be a good method to increase dorsoventral displacement of the center of gravity and total power, which appear to be locomotor characteristics desirable for dressage, jumping and three-day event competitions. In addition, we have demonstrated that these changes persist during terrestrial locomotion. Further, WT can be used for rehabilitation of chronic tendinitis of the flexor digital tendon, chronic desmitis of the suspensory ligament and other ligament injuries, as well as for chronic osteoarthritis. Considerable improvements have been reported in horses with osteoarthritis compared to other types of exercises, and therefore, this type of exercise is highly recommended in these cases.

Conflicts of Interest: There is no potential conflict of interest, and the authors have nothing to disclose. This work was not supported by any grant.

References

1. Steel, C.M., Bond, B.M., Morrice-West, A.V. (2019). Survey of trainers on the use of swimming exercise for Standardbred racehorses in Australia. Aust. Vet. J. 97(3):61-67.
2. King, M.R., Haussler, K.K., Kawcak, C.E., McIlwraigh, C.W., Reiser II R.F. (2013). Effect of underwater treadmill exercise on postural sway in horses with experimentally induced carpal joint osteoarthritis. Am. J. Vet. Res. 74, 971-982.
3. King, M.R., Haussler, K.K., Kawcak, C.E., McIlwraith, C.W., Reiser, R.F. 2nd, Frisbie, D.D., Werpy, N.M. (2017). Biomechanical and histologic evaluation of the effects of underwater treadmill exercise on horses with experimentally induced osteoarthritis in the middle carpal joint. Am. J. Vet. Res. 78:558-569.
4. Wilson, J.M., McKenzie, E., Duesterdieck-Zellmer, K. (2018). International survey regarding the use of rehabilitation modalities in horses. Front. Vet. Sci. Jun11;5:120. doi:10.3389/fvets.2018.00120.
5. Muñoz, A., Saitua, A., Becero M., Riber, C., Satué, K., Sánchez de Medina, A., Argüelles, D., Castejón-Riber, C. (2019). The use of the water treadmill for the rehabilitation of the musculoskeletal injuries in the sport horse?. J. Vet. Res. 63(3), 439-445.
6. Bonelli, F., Sgorbini, M., Meucci, V., Sighieri, C., Baragli, P. (2017). How swimming affects plasma insulin and glucose concentration in Thoroughbreds: a pilot study. Vet. J. 226:1-3.
7. King, M.R. (2016). Principles and application of hydrotherapy for equine athletes. Vet. Clin. North Am.: Equine Pract. 32, 115-126.

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

8. Hobo, S., Yoshida, K., Yoshihara, T. (1998). Characteristics of respiratory function during swimming exercise in thoroughbreds. J. Vet. Med. Sci. 60, 687-689.
9. Nankervis K.J., Launder E.J., Murray R.C. (2017). The use of treadmills within the rehabilitation of horses. J. Equine Vet. Sci. 53, 108-115.
10. Adair, H.S. III. (2011). Aquatic therapy for conditioning and treatment of tendon and ligament injuries. In: 57th Annual Convention of the American Association of Equine Practitioners Proceedings, San Antonio, Texas, pp. 181–185.
11. Greco-Otto, P., Baggaley, M., Edwards, W.B., Léguillete, R. (2019). Water treadmill exercise reduces equine limb segmental accelerations and increases shock attenuation. BMC Vet. Res. 15(1), 329. Doi:10.1186/212917-019-2075-6.
12. Saitua, A., Becero M., Castejón-Riber C., Riber, C., Argüelles, D., Sánchez de Medina, A.L., Muñoz, A., (2019). Accelerometric parameters measured in the fore- and hindquarters in horses during an exercise session on a water treadmill at different water depths. In: Proc. XXIV International Meeting of the Spanish Society of Veterinary Surgery, Córdoba, Spain, 2019, 293-299.
12. Muñoz, A. (2018). Exercise in water in the horse: physiological adaptations and potential benefits for training and rehabilitation. In: Proc. Veterinary Animal Science Days, University of Milan, Italy.
Borgia L.A., Valberg S.J., Essén-Gustavsson B. (2010). Differences in the metabolic properties of the gluteus medius and superficial digital flexor muscles and the effect of water treadmill training in the horse. Equine Vet. J. 38, 665–670.
13. Muñoz, A., Santisteban, R., Rubio, M.D., Agüera, E.I., Escribano, B.M., Castejón, F.M. (1999). Locomotor, cardiocirculatory and metabolic adaptations to training in Andalusian and Anglo-Arabian horses. Res. Vet. Sci. 66(1):25-31.
14. Muñoz, A., Santisteban, R., Rubio, M.D., Vivo, R., Agüera, E.I., Escribano, B.M., Castejón, F.M. (1997). The use of functional indexes to evaluate fitness in Andalusian horses. J. Vet. Med. Sci. 59(9):747-752.
15. Firshman, A.M., Borgia, L.A., Valberg, S.J. (2015). Effects of training at a walk on conventional and underwater treadmills on fiber properties and metabolic responses of superficial digital flexor and gluteal muscles to high speed exercise in horses. Am. J. Vet. Res. 76, 1058-1065.
16. Méndez-Angulo, J.L., Firshman, A.M., Groschen, D.M., Kieffer, P.J., Trumble, T.N. (2013). Effect of water depth on amount of flexion and extension of joints of the distal aspects of the limbs in healthy horses walking on an underwater treadmill. Am. J. Vet. Res. 74, 557-566.
17. Muñoz, A., Castejón-Riber C., Riber C., Esgueva M., Méndez-Angulo J., Mateo S., Castejón F (2016). Cambios locomotores determinados mediante acelerometría en caballos ejercitados en treadmill acuático a diferentes profundidades de agua. In: Proc. XVII Congreso Internacional de Medicina y Cirugía Equina, Sevilla, Spain, 2016, 39-41.
18. Riber, C., Castejón-Riber, C., Esgueva, M., Méndez-Angulo, J.L., Castejón, F., Muñoz, A. (2016). Cambios cinemáticos beneficiosos para rehabilitación en caballos ejercitados en treadmill acuático. In: International Meeting of the Spanish Society of Veterinary Surgery, April 15-16, Madrid, Spain.
19. Saitua, A., Becero, M., Castejón-Riber, C., Argüelles, D., Sánchez de Medina, A., Muñoz, A. (2019). Total power measured with accelerometry in horses exercised on a water treadmill at different water depth and velocities. In: Meeting of the European Society of Veterinary Sport Medicine and Rehabilitation ESVSMR, Ghent, Belgium.
20. Barrey, E. (2014). Biomechanics of locomotion in the athletic horse. In: Equine Sports Medicine and Surgery (Hinchcliff, K.W., Kaneps, A.J., Geor, R.J., Eds). Saunders Elsevier, pp. 189-211.
Biau, S., Barrey, E. (2004). Relationships between stride characteristics and scores in dressage tests. Pferdeheilkunde 20(2), 1-4.
21. Vida, T., Castejón-Riber, C., Riber, C., Saitua, A., Becero, M., Méndez-Angulo, J.L., Roldán, J., Muñoz, A. (2018). Ejercicio en cinta rodante acuática en la rehabilitación de un caballo con osteoartritis múltiple crónica. In: Congreso Internacional de Medicina y Cirugía Equina. Noviembre 16-17, Sevilla, Spain.
22. Becero, M., Saitua, A., Reguera, M., Castejón-Riber, C., Herrera, R., Muñoz, A. (2018). Ejercicio en treadmill acuático en la rehabilitación de un caballo con tendinopatía del flexor digital

ISSN 1828-6550
DOI: 10.6092 / 1828-6550 / APMB.107.2.2019.SD3

superficial. In: II Congreso de Veterinaria y Ciencia y Tecnología de los alimentos, February 9, Córdoba, Spain.
23. Nankervis K.J., LeFrancois K. (2018). A comparison of protraction-retraction of the distal limb during treadmill and water treadmill walking in horses. J. Equine Vet. Sci., 70, 57-62.
24. Mooij, M.J., Jans, W., den Heijer, G.J., De Pater, M., Back, W. (2013). Biomechanical response of the back of riding horses to water treadmill exercise. Vet. J. 198, 120-123.
25. Nankervis K.J., Finney P., Launder L. (2016). Water depth modifies back kinematics of horses during water treadmill exercise. Equine Vet. J. 48, 732–736.

Communicated and received June 24, 2019, revised Sept 25, 2019, published on line Nov 11, 2019