INTRODUCTION

Swimming is a well established method amongst trainers and owners, often used as a means of conditioning and rehabilitating horses. Most importantly, it provides a low risk of injury as the horse is not subjected to the pounding that track or field work can have on the joint.

Swimming has also been found to be highly effective for treating horse diseases such as arthritis and tendonitis. As a form of exercise, swimming is used with horses as a part of their training regimen, particularly when lameness exists (Thomas et al., 1980). In addition to building basic muscle tone, it provides exercise, promotes the development of underutilized muscles, and expands and strengthens the heart and lungs.

Water power, buoyancy, and water resistance influence the effects of swim training. This type of training provides a considerable amount of exercise in a short amount of time as a result of the increased intensity and decreased impact on the legs (Waran, 2002). Also, water power develops pectoral muscles by enhancing breathing and increasing lung capacity (Pluim et al., 2000; Fagard, 2003). Moreover, the power of pushing through water resistance builds up olfactory groove muscles, as every muscle of the body is used during active propelling exercise. Therefore, due to its effects on enhancing heart and lung function, and physical fitness in general, propulsion swim training is frequently utilized with horses to increase their endurance (Davie et al., 2008).

Prior studies have concentrated on how swim training affects the equine cardiovascular and respiratory systems (Asheim et al., 1970; Misumi et al., 1994; Jones et al., 2002). Research in both humans and horses supports the existence of a relationship between left ventricular mass and maximal oxygen uptake. Equine studies using echocardiography also show a correlation between heart score and maximal oxygen uptake (Young et al., 2002).

Swimming is an excellent exercise for enhancing the endurance of racehorses rather than addressing slow twitch muscle fibers. Previous studies have investigated the effectiveness of a swimming exercise test for evaluating changes in performance measures, skeletal muscle composition (Misumi et al., 1994, 1995), and respiratory function (Hobo et al., 1998). However, previous studies, have not established the physiological benefits of swim training for horses; therefore, the aim of this study was to examine the effect of swim training duration on physiological characteristics in Jeju crossbred riding horses.

ABSTRACT: The changes in physiologic parameters by swim exercise duration were examined in five female well-trained Jeju crossbred riding horses that had riding experience of more than three years without swim training experience. The horses were performed with swim exercise for 10 min (60.0 m/min) once a day for 14 days. Physiologic characteristics and haematic parameters were measured before swimming, immediately after swimming, and after a 10 min rest at first day (D0), 7 days (D7), and 14 days (D14) of training. After 14 days of swim training, heart rate (p<0.05), blood glucose (p<0.05), lactate concentration (p<0.001), packed cell volume (p<0.01), and hemoglobin (p<0.01) measured immediately after swim and after 10 min rest showed significant lower values than those of D0. The results illustrate the benefits of swim training for riding horses and the need for the establishment of swimming routines of appropriate duration and intensity to maximize the advantages of swim training. (Key Words: Equine, Physiologic Parameters, Exercise, Swim, Training)
MATERIALS AND METHODS

Animals
A total of five Jeju crossbred horses (Thoroughbred×Jeju native) from riding centers on Jeju Island were used for this study. The horses participated five females, weighing 318±18.5 kg with a mean age of 6.6±1.3 years.

The horses had riding experience more than three years. However, they have never tried swimming training. All horses were clinically healthy prior to the swimming experience. This study was approved by the Animal Ethics Committee of Jeju National University, Korea.

Experimental design
This study was performed to determine effects on physiologic variables according to swim training duration. The training track used had a circumference of 30 m, a depth of 1.8 m and a width of 3 m and was performed for 10 min once a day for 14 days. Each horse completed 20 laps (60.0 m/min) for swim training (Figure 1).

The swim training durations evaluated were: first day (D₀), 7 days (D₇), and 14 days (D₁₄) of training. Physiological characteristics, blood glucose, lactate concentration, packed cell volume (PCV), total protein (TP), and hemoglobin (Hb) were measured before swimming, immediately after swimming, and after a 10 min rest. Prior studies, as to 15 min cool down exercise groups, level of lactic acid as indicator of fatigue substance was recovered to 75%, 58%, 45.3% respectively in TR15, WR15 and R15 group, which means that recovery was efficiently achieved in active groups than passive groups (Kang et al., 2011). Therefore, the rest period consisted of trotting on a treadmill.

Heart rate (HR) measurements and blood analysis
HR was also measured before swimming, immediately after swimming, and after a 10 min rest with a T31 Polar transmitter (Polar Equine, Finland). Blood samples were taken from the jugular vein with a 21-gauge needle using Vacutainer® collection tubes. Blood lactate concentrations were analyzed using an LT-1710 L-Pro lactate analyzer (ARKRAY Inc., Japan) and glucose concentrations were calculated using the Accu-Chek Go system (Roche, Germany). PCV, TP, and Hb were analyzed at the clinical pathology laboratory of the veterinary teaching hospital at Jeju National University.

Statistical analysis
Data were analyzed using a two-way analysis of variance (ANOVA) for repeated measures with points before swim, after swim, and 10 min after rest at training periods D₀, D₇, and D₁₄. All data is reported as means±SD with a significance level of p<0.05 using SAS version 8 (SAS Institute Inc., Cary, NC, USA). Person correlation coefficients were evaluated to describe the relationship between variables using partial correlation coefficients (CORR procedure of SAS).

RESULTS

Swim training
The aim of this study was to evaluate the physiologic effects of swim training over a two-week duration. The mean speed of the horses during training was 60.0 m/min. This study was conducted to determine effects on physiologic variables according to swim training duration. The training track used had a circumference of 30 m, a depth of 1.8 m and a width of 3 m and was performed for 10 min once a day for 14 days.

Heart rate
After swim training HR was highest immediately after exercise but gradually decreased (p<0.001). At 10 min after rest, D₇ and D₁₄ showed significant decreases in HR compared to D₀ (Figure 2A). HR was positively related to lactate (r = 0.719; p<0.001), glucose (r = 0.574; p<0.01), and PCV (r = 0.473; p<0.001).
Figure 2. Relative changes of physiologic and haematic parameters of horses after swim training. A, heart rate; B, glucose concentration; C, lactate concentration; D, packed cell volume; E, total protein; F, hemoglobin. a,b Means with different superscripts significantly differ (p<0.05).

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Table 1. Effect of swim training duration on physiologic variables of horses

| Variables                          | Measurement time | Swim training duration (days) | Significance |
|-----------------------------------|------------------|-------------------------------|--------------|
|                                   |                  | 0                            | 7            | 14           |              |
| Heart rate (beats/min)            | Before swim      | 50.8±20.76                   | 49.60±10.45  | 44.00±4.24   | NS           |
|                                   | After swim       | 148.8±19.0                   | 124.2±19.1   | 132.0±27.6   | *            |
|                                   | 10 min after rest| 93.4±30.9                    | 82.8±11.8    | 70.0±10.4    | *            |
| Blood glucose concentration (mmol/L) | Before swim   | 80.60±21.00                  | 97.60±17.22  | 86.60±11.76  | NS           |
|                                   | After swim       | 118.4±18.2                   | 110.0±21.5   | 93.6±11.4    | *            |
|                                   | 10 min after rest| 116.6±18.6                   | 104.6±17.6   | 82.4±16.0    | ***          |
| Blood lactate concentration (mmol/L) | Before swim   | 0.80±3.20                    | 0.30±2.03    | 0.22±1.02    | NS           |
|                                   | After swim       | 13.03±3.17                   | 6.40±2.91    | 4.66±2.37    | ***          |
|                                   | 10 min after rest| 9.96±4.57                    | 3.28±3.27    | 2.12±0.76    | ***          |

Levels of significance: NS = Not significant; * p<0.05; ** p<0.01; *** p<0.001.

Table 2. Effect of swim training duration on haematic parameters of horses

| Variables         | Measurement time | Swim training duration (d) | Significance |
|-------------------|------------------|----------------------------|--------------|
|                   |                  | 0                          | 7            | 14           |              |
| Packed cell volume (%) | Before swim      | 35.8±7.15                  | 41.20±15.15  | 36.80±5.16   | NS           |
|                   | After swim       | 59.40±8.68                 | 45.40±4.35   | 42.40±10.8   | ***          |
|                   | 10 min after rest| 52.00±8.68                 | 37.80±9.03   | 37.60±10.59  | **           |
| Total protein (g/dl) | Before swim      | 7.04±0.71                  | 6.88±1.04    | 7.12±0.86    | NS           |
|                   | After swim       | 8.08±0.83                  | 7.30±0.64    | 7.32±1.01    | NS           |
|                   | 10 min after rest| 7.54±0.86                  | 6.96±0.73    | 6.82±0.84    | NS           |
| Hemoglobin (g/dl)   | Before swim      | 18.33±3.11                 | 11.52±2.25   | 13.66±4.55   | *            |
|                   | After swim       | 23.33±0.72                 | 14.38±4.77   | 17.68±6.16   | **           |
|                   | 10 min after rest| 22.53±1.15                 | 11.06±5.11   | 14.90±6.92   | ***          |

Levels of significance: NS = Not significant; * p<0.05; ** p<0.01; *** p<0.001.

Glucose

The differences in blood glucose levels among the training periods are shown in Table 1 and Figure 2B. The D14 stage had significantly lower blood glucose levels than D0 and D7 (p<0.001). In this study, criteria of comparison employed to measure the change in recovery rate are fixed to 100%, which is the condition right after exercise. Figure 2 shows the recovery rate according to the type and time of rest and all figures are converted into a percentage. Blood glucose levels showed a strong relationship with lactate levels (r = 0.716; p<0.001).

Lactate

Blood lactate levels before training at all stages were less than 1 mol/L and all stages experienced the greatest increase in blood lactate immediately after training (p<0.001), and then tended to decrease with the training period. In particular, the D7 stage had significantly reduced concentrations compared to D0 (Table 1 and Figure 2C). Blood lactate levels were positively related to PCV, Hb, and TP.

Packed cell volume

Table 2 shows the PCV in relation to training periods at different time points. D7 and D14 had lower PCV values than D0 after training (p<0.001). Comparing of according to swim training duration in immediately after training and 10 min rest, in D7 and D14, all stages showed similar levels. PCV showed a positive relationship with TP (r = 0.521; p<0.001), and Hb (r = 0.529; p<0.001).

Total protein

The levels of blood TP for the training period at the different time points are shown in Table 2. The level of TP did not significantly differ among the training periods. Also, 10 min after rest, all levels recovered to what they were before the start of training; however, recovery rates of TP immediately after training was more efficient at D7 and D14 than at D0.

Hemoglobin

Hb values at D7 and D14 were significantly decreased compared to D0, but D7 values recovered during the rest...
Levels of significance: **p<0.01; ***p<0.001.

**DISCUSSION**

It is well known that high intensity training results in an increase in the oxidative enzyme activity of muscle (Pluim et al., 2000; Fagard, 2003; Davie et al., 2008). Muscle and blood homeostasis may dramatically change under exercise conditions (Westerblad and Allen, 2003) and continuous efforts cannot be effectively applied unless an adequate restoration of homeostasis occurs (Toubekis et al., 2008).

Certain hematological adaptations are necessary to guarantee an adequate supply of oxygen and blood-borne substrates to active muscles during exercise and for the removal of metabolites (Piccione et al., 2007). The body must be properly prepared if the benefits of exercise are to be garnered safely. This study was performed to identify physiological changes in horses during two weeks of swim training. Each animal circled the swim track for 20 laps (60.0 m/min) during the swim training. The results indicated that changes in physiological traits following swim training were dependent upon the training period. Kang et al. (2012) Asian-Aust. J. Anim. Sci. 25(2):200-206

| Heart rate | Glucose | Lactate | PCV | TP |
|------------|---------|---------|-----|----|
| Glucose    | 0.574** |         |     |    |
| Lactate    | 0.719*** | 0.716***|     |    |
| Packed cell volume | 0.473*** | 0.423** | 0.639*** |    |
| Total protein | 0.424** | 0.126 | 0.393** | 0.521*** |
| Hemoglobin | 0.241 | 0.229 | 0.525*** | 0.529*** |

Blood lactate concentration tended to decrease depending on the training period. In particular, it was significantly reduced at D 7 compared to D 0. When comparing each value immediately after exercise, D 0, D 7, and D 14 lactate production was 1,600%, 800%, 580%, respectively. These results indicated that lactic acid formation diminished as the duration of training increased. In addition, recovery rate at D 14 was even faster than that at D 0. Both D 7 and D 14 lactate levels decreased below 4 mmol/L after a 10 min rest, which showed no excess recovery. The reduction of blood lactate reflects the improved metabolic efficiency of the horses. Kang et al. (2011) reported the lactate concentration level recovered to the threshold of 4 mmol after 15 min rest in the high-intensity exercise (Kang et al., 2011). Also, Piccione et al. (2010) reported on a trot group with a very low lactate accumulation level after exercise (Piccione et al., 2010).

In this study, PCV, an estimate of the volume of red blood cells, was used to evaluate dehydration and anemia. Typically, the optimum level of PCV in horses is close to 40%, and levels below 32% or above 48% indicate problems. Below 30% of PCV is considered anemic, and efforts should be made to identify the reason for the lack of red cells. This study identified significant changes in PCV immediately after training and after a 10 min rest compared to levels prior to training.

TP of blood was also measured as an aid in estimating hydration status. There were no significant differences when comparing stages. Hb levels showed a quick recovery rate compared to levels prior to training. Also, when glucose level in the D 14 stage is the result of fast recovery from high-intensity training. Previous studies showed an increase in blood lactate concentration in anaerobic metabolism of horses (Ferraz et al., 2007, 2008; Piccione et al., 2010).

Onset of blood lactate accumulation (4 mmol/L) has been used as a criterion to evaluate the exercise capacity of horses (Gondim et al., 2007; Lindner et al., 2009; Piccione et al., 2010). Thus, lactate production and removal are very important during anaerobic exercise and relevant to the interpretation of blood lactate concentrations (Gondim et al., 2007). The results in this study showed the marked increase of blood lactate level immediately after training (p<0.001).

Period. Hb levels were positively related to lactate (r = 0.525; p<0.001) and PCV (r = 0.529; p<0.001).

**Table 3. Correlation coefficients (r) among physiologic and haematiologic parameters of horses**
comparing immediately before and after the training, the 
recovery rate of Hb immediately following exercise 
dramatically declined compared to what it was before 
exercise. Taken together, the changes realized after training 
demonstrate the effects of swimming on physiological 
adaptation of the horses. Jones et al. (2002) found peak 
expiratory pressures in horses to be higher during 
swimming than galloping and that horses breath five times 
slower while swimming than galloping.

In horses, aerobic training escalates cardiopulmonary 
function, muscular strength, and blood release rate by 
strengthening the heart, which causes less fatigue despite 
rapid running. In addition, anaerobic training gives rise to 
rapid fatigue recovery by decreasing physical energy output 
when the horse speeds up enhancing removal of 
accumulated fatigue materials. Therefore, aerobic and 
aerobic methods should be combined in horse training. 
This study has great significance in that it is the very first 
study to consider the effectiveness of swim training on 
riding horses. Equine blood lactate concentration is 
generally below 1 mmol/L. With increased exercise 
intensity, concentrations below 4 mmol/L indicate aerobic 
exercise whereas levels above 4 mmol/L indicate anaerobic 
exercise.

According to a study by Knudsen and Jrgensen (2000), 
swimming was observed to decrease lactic acid formation 
more than an average quick pace on land, and as such is 
considered a viable substitute training method to reduce 
injuries resulting from excessive tension. In addition, 
swimming is seen as an effective means to train the 
cardiovascular system as well as both aerobic and anaerobic 
muscle capacity. Davie et al. (2008) also reported that 
swimming produced less lactic acid formation than track 
training. Knudsen and Jrgensen (2000) suggested that 
swimming could be substituted for the traditional training 
of horses in order to improve the cardiovascular system and 
the aerobic and anaerobic capacities of the musculature. 
Swim training is considered an effective method in terms of 
maintaining or developing equine cardiovascular function.

In conclusion, after 14 days of swim training, heart rate 
(p<0.05), blood glucose (p< 0.05), lactate concentration 
(p<0.01), packed cell volume (p<0.01), and hemoglobin 
(p<0.01) measured immediately after swim and after 10 min 
rest showed significant lower values than those of D0. 
Horses in this study demonstrated rapid lactate recovery 
(below 4 mmol/L) during both swim training sessions after 
a 10 min rest (Table 1). Lactate concentrations at D0, D3, 
and D14 immediately after exercise were 13.03±3.17, 
6.40±2.91, and 4.66±2.37 mmol/L. Lactic acid formation 
dramatically diminished compared to levels prior to 
swimming, indicating a large difference depending on 
training periods. These results illustrate the benefits of 
swim training for riding horses and the need for the 
establishment of swimming routines of appropriate duration 
(despite the short period of two weeks) and intensity to 
maximize the advantages of swim training.

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