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Physiological Changes in Jeju Crossbred Riding Horses by Swim Training

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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 (D_0), 7 days (D_7), and 14 days (D_{14}) 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 D_0. 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)

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.

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Period 1	Period 2		Period 3	
Measurement of horses	Swim Training for 7 days (10 min once a day)	Measurement of horses	Swim Training for 7 days (10 min once a day)	Measurement of horses
D_0	←→ 20 laps (60.0 m/min)	D_7	←→ 20 laps (60.0 m/min)	D_{14}

Figure 1. Diagram of experimental design.

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. Training 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 (D_0), 7 days (D_7), and 14 days (D_{14}) 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 D_0, D_7, and D_{14}. 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, D_7 and D_{14} showed significant decreases in HR compared to D_0 (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; $p<0.001$).

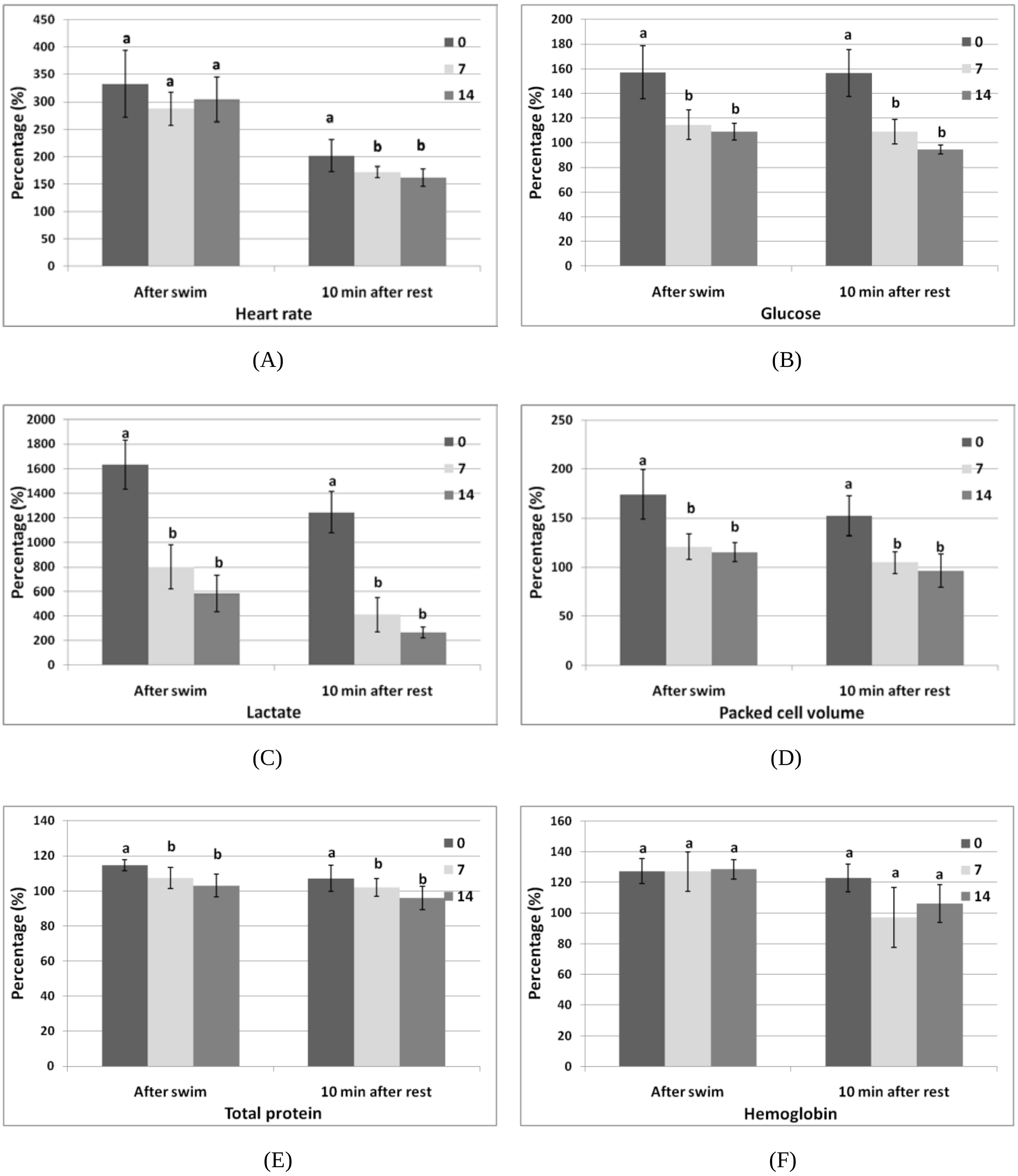

Figure 2. Relative changes of physiologic and haematic parameters of horses after swim training. A, heart rate; B, glucose concentration; C, lactate concentration; D, packed cell volume; E, total protein; F, hemoglobin. [a,b] Means with different superscripts significantly differ ($p<0.05$).

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	50.80 ^{a}±20.76	49.60 ^{a}±10.45	44.00 ^{a}±4.24	NS
	After swim	148.8 ^{a}±19.0	124.2 ^{b}±19.1	132.0 ^{ab}±27.6	*
	10 min after rest	93.4 ^{a}±30.9	82.8 ^{ab}±11.8	70.0 ^{b} ±10.4	*
Blood glucose concentration (mmol/L)	Before swim	80.60 ^{a}±21.00	97.60 ^{a}±17.22	86.60 ^{a}±11.76	NS
	After swim	118.4 ^{a}±18.2	110.0 ^{a}±21.5	93.6 ^{b}±11.4	*
	10 min after rest	116.6^{a}±18.6	104.6^{a}±17.6	82.4 ^{b}±16.0	***
Blood lactate concentration (mmol/L)	Before swim	0.80 ^{a}±3.20	0.30 ^{a}±2.03	0.22 ^{a}±1.02	NS
	After swim	13.03^{a}±3.17	6.40 ^{b}±2.91	4.66 ^{b}±2.37	***
	10 min after rest	9.96^{a}±4.57	3.28 ^{b}±2.37	2.12 ^{b}±0.76	***

Levels of significance: NS = Not significant; * p<0.05; *** p<0.001.
[a,b] Means with different superscripts in the same row significantly differ (p<0.05).

Glucose

The differences in blood glucose levels among the training periods are shown in Table 1 and Figure 2B. The D_{14} stage had significantly lower blood glucose levels than D_0 and D_7 (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 D_7 stage had significantly reduced concentrations compared to D_0 (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. D_7 and D_{14} had lower PCV values than D_0 after training (p<0.001). Comparing of according to swim training duration in immediately after training and 10 min rest, in D_7 and D_{14}, 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 D_7 and D_{14} than at D_0.

Hemoglobin

Hb values at D_7 and D_{14} were significantly decreased compared to D_0, but D_7 values recovered during the rest

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	35.80 ^{a}±7.15^{A}	41.20 ^{a}±15.15	36.80 ^{a}±5.16	NS
	After swim	59.40^{a}±8.68	45.40^{b}±4.35	42.40^{b}±10.8	***
	10 min after rest	52.00 ^{a}±8.68	37.80 ^{b}±9.03	37.60 ^{b}±10.59	**
Total protein (g/dl)	Before swim	7.04^{a}±0.71	6.88 ^{a}±1.04	7.12 ^{a}±0.86	NS
	After swim	8.08 ^{a}±0.83	7.30 ^{a}±0.64	7.32 ^{a} ±1.01	NS
	10 min after rest	7.54 ^{a} ±0.86	6.96 ^{a}±0.73	6.82 ^{a}±0.84	NS
Hemoglobin (g/dl)	Before swim	18.33 ^{a}±0.11	11.52 ^{b}±2.25	13.66 ^{ab}±4.55	*
	After swim	23.33 ^{a}±0.72	14.38^{b}±4.77	17.68 ^{b}±6.16	**
	10 min after rest	22.53^{a}±1.15	11.06^{b}±5.11	14.90^{b}±6.92	***

Levels of significance: NS = Not significant; * p<0.05; ** p<0.01; *** p<0.001.
[a,b] Means with different superscripts in the same row significantly differ (p<0.05).

Table 3. Correlation coefficients (*r*) among physiologic and haematic parameters of horses

Heart rate	HR	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***	0.137

Levels of significance: ** p<0.01; *** 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).

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.

Immediately after exercise, there were significant differences in HR during the D_7 training period compared to D_0 (p<0.001). If the rate prior to exercise was considered as 100%, when compared to immediately after exercise and after a 10 min rest, the D_{14} stage showed the fastest decrease in HR (~142%). In this experiment, the pre-training HR ranged from 44 to 51 beats/min and post-training from 124 to 149 beats/min. The HR (170-180 beats/min; max 75-80%) of a race horse indicates that anaerobic metabolism occurs greatly during exercise due to the significant increase in lactate concentration to threshold levels following anaerobic exercise (Gondim et al., 2007; Ferraz et al., 2008). It is considered that the training of a riding horse is less restrictive than that of a racehorse in terms of speed during ordinary training procedures.

Regarding blood glucose concentration after exercise, D_0 and D_7 stages had similar values but D_{14} had significantly different values (p<0.001). The decreasing rates at D_{14}, D_7, and D_0 stages were approximately 14%, 5.58%, and 0.58%, respectively. It is suggested that the 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).

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 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 anaerobic 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 ($p<0.001$), 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 D_0. 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 D_0, D_7, and D_{14} 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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