

# Changes in Lactate Levels and Blood Cell Composition in Hokkaido Native Horses after exercise Simulating Yabusame (Traditional Japanese Mounted Archery)

**Keywords:** Japanese mounted archery; Hokkaido native horses; Lactate concentration; Blood components; Equine physiology

## Abstract

The history of Yabusame (traditional Japanese mounted archery) as a modern sport is short, and only a few physiological studies have been conducted on the horses used. Therefore, this study investigates changes in blood cell composition and lactate levels of Hokkaido native horses used for Yabusame to determine whether the current exercise regimens are appropriate. We conducted the same experiment at two Yabusame horseback riding facilities, each using four horses of the Hokkaido native breed. In Experiment 1, blood samples were taken at three time points (while stationary, after preparatory exercise, and after horses had cantered five times on a 170 m track to simulate the Yabusame competition). In Experiment 2, blood samples were taken at four time points (while stationary, after walking for ~10 min to the racetrack, after preparatory exercise, and after cantering five times on a 150 m track to simulate competition). Lactate Pro and a blood cell counter were used to measure lactate levels and blood cell components, respectively. In Experiment 1, lactate concentration, red blood cell count, and hemoglobin were significantly ( $p < 0.05$ ) higher after exercise than the baseline. In Experiment 2, both lactate concentration and hemoglobin levels rose significantly ( $p < 0.05$ ) from stationary levels after walking to the track and performing the preparatory exercise. However, lactate concentration remained within the physiological range ( $< 4$  mmol/L, a threshold that indicates fatigue in horses) even after the elevated physical activity. Therefore, the exercise tested in this study did not impose an excessive physiological burden on the horses.

## Introduction

Yabusame (traditional Japanese mounted archery) originated about 1,000 years ago as a sport designed to improve shooting arrows from a galloping horse, a dominant form of ancient warfare [1]. In modern Japan, Yabusame is primarily a Shinto ritual, with different regional forms passed down from generation to generation. At shrines, Yabusame involves multiple ceremonies, often with strict rules of etiquette and restrictions on participation. This visibility, coupled with an increasing interest in historical traditions, has spurred a movement to enjoy such mounted archery safely as a sport. Thus, the Japan Yabusame Federation was established in the Tokachi area of Hokkaido in 2002. Over the past 20 years, the organization formulated rules and regulations for Yabusame while promoting the sport. As the number of enthusiasts and world-class competitions increased, Yabusame developed into a major tourist attraction that is expected to economically benefit the region [2].

Yabusame involves shooting arrows at multiple targets while



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riding a galloping horse along a set racecourse, with total points tallied at the end. Horses must be of Japanese breed, although any size is acceptable. The competition field is approximately 180-200 m long and 2.5-3 m wide, with targets spaced 50-60 m apart while being 3-4 m away from the archer [2]. In addition to having formalized competitive structure, clear regulations have also been put in place regarding human equipment (e.g., helmets, protectors, type of bow) and horse equipment (e.g., saddle type). However, no rules have been set on the number of times a horse can run, although past organizers have indicated that they typically run four to six times.

The horse usually used for Yabusame in Hokkaido is a native Japanese breed originating in Hokkaido. They are small at approximately 125-135 cm in height and 350-400 kg in weight. Owing to their low sway at trot and mild nature [3,4], these Hokkaido horses are also a common choice for less experienced riders, outdoor riding such as trekking, and horse therapy. However, in 2022, the number of registered horses dropped to 1,083 [5], a 64% decrease compared to the year 2000, indicating a need to protect this native breed. In particular, given their popularity in Yabusame, more data is required to understand their physical limits. This would provide a scientific basis for rules regarding the number of times the horse should run during competitions. Therefore, this study was conducted to simulate the physical efforts of horses during the actual Yabusame competition. Furthermore, changes in lactate, red blood cell count, hemoglobin, and hematocrit levels were measured to evaluate whether the number of runs is appropriate and does not place excessive burden on the horses. This is the first study to measure these physiological parameters in Hokkaido native horse breeds during exercise.

## Materials & Methods

All protocols were approved by the Ethics Committee on the Use of Animals from the Obihiro University of Agriculture and Veterinary Medicine (approval number 21-138). Two sets of the same experiments (Experiments 1 and 2) were conducted at two locations.

### Experiment site and date

Experiment 1 was conducted on October 13, 2021, at a mounted archery competition track (approximately 170m) in a Hokkaido

native horse breeding ranch located in Memuro (Hokkaido prefecture, Japan). Experiment 2 was conducted on October 14, 2021, at another mounted archery competition track (approximately 150m) in a riding club in Memuro.

Test animals and riders

Experiment 1 used four Hokkaido native horses, two geldings and two mares aged 2-14 years old. Experiment 2 also used four Hokkaido native horses, three geldings and one mare aged 4-17 years old. All eight horses previously participated in Yabusame competitions and were well acclimated to the tracks used in the experiments.

All participating riders (three women and two men) had between 5-25 years of riding experience, with sufficient riding skills for the simulated competition runs conducted in the experiments.

Experimental procedures

Experiment 1 was performed twice with two horses each (Figure 1). Initial blood samples were taken immediately after horses were saddled. Thereafter, horses were ridden to the competition track, where the rider performed a preparatory exercise involving one walk followed by one trot around the track before a second blood sample was taken. Participants then performed a simulated competition run involving five canters (approximately 400 m/min) before a third blood sample was obtained.

In Experiment 2, all horses were tested simultaneously (Figure 2). Again, the first blood sample was taken immediately after saddling. Horses were walked to the competition track (approximately a 10-minute journey), where a second blood sample was taken. Riders then performed the same preparatory exercise as in Experiment 1, and a third blood sample collection followed. Finally, participants engaged in the simulated competition run (see Experiment 1) before a fourth blood sample was obtained.

Blood sampling and analysis

Blood was sampled from the jugular vein of stationary horses without riders, then placed either in tubes containing 5 mL sodium heparin (sterile Bectoject vacuum blood collection tubes, Terumo Corporation, Tokyo, Japan) for measuring blood lactate or in tubes containing 5m EDTA 2Na for measuring blood cell components (sterile Bectoject vacuum blood collection tubes, Terumo Corporation,

Tokyo, Japan). Thereafter, tubes were quickly chilled in ice and transferred to the laboratory about 2 hours.

Blood lactate levels were measured immediately after samples were brought back to the laboratory using Lactate Pro<sup>2</sup> (Arkray Inc., Kyoto, Japan). Variables related to blood cell components (red blood cell count, hemoglobin volume, and hematocrit value) were measured the next day between 10:00 and 12:00 with a fully automatic blood cell counter (MEK 6550 Seltac  $\alpha$ , Nihon Kohden Corporation, Tokyo, Japan). The lactate levels and blood components were compared before and after the exercise to assess the physiological level of the horses' effort.

Statistical analysis

Blood lactate, red blood cell count, hemoglobin, and hematocrit data of four horses per experiment were averaged and then compared between the different blood sampling timing (before and after the simulated competition) using Tukey's multiple comparisons. Data from Experiments 1 and 2 were analyzed separately. All analyses were performed in R (version 4.1.1) software. Significance was set at  $p < 0.05$ .

Results

Experiment 1

The blood lactate of four horses was significantly ( $p < 0.05$ ) higher after simulated competition than the stationary time point and after the preparatory exercise (Table 1). Red blood cell count and hemoglobin levels were also significantly ( $p < 0.05$ ) higher after simulated competition than the stationary stage and after the preparatory exercise. However, average hematocrit values did not differ significantly pre- and post-exercise (simulated competition).

Experiment 2

Blood lactate values were significantly ( $p < 0.05$ ) higher after walking to the track than before the preparatory exercise (Table 2). Blood red blood cell count and hematocrit values did not differ

**Table 1:** Average blood lactate levels and blood cell composition (average  $\pm$  S.E.) of Hokkaido native horses at each sampling timing in Experiment 1.

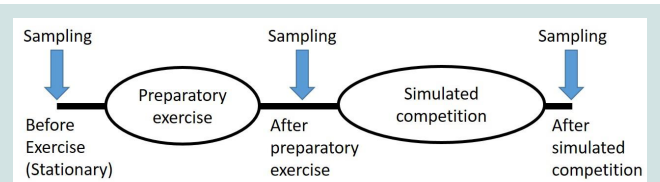
	While stationary	After preparatory exercise	After simulated competition
Lactate levels (mmol/L)	1.23 $\pm$ 0.09 <sup>a</sup>	1.20 $\pm$ 0.09 <sup>a</sup>	1.60 $\pm$ 0.09 <sup>b</sup>
Red blood cell count (10 <sup>9</sup> / $\mu$ L)	767 $\pm$ 0.12 <sup>a</sup>	790 $\pm$ 0.12 <sup>a</sup>	818 $\pm$ 0.12 <sup>b</sup>
Hemoglobin (g/dL)	11.2 $\pm$ 0.48 <sup>a</sup>	10.8 $\pm$ 0.48 <sup>a</sup>	13.8 $\pm$ 0.48 <sup>b</sup>
Hematocrit (%)	46.9 $\pm$ 0.68	46.9 $\pm$ 0.68	49.6 $\pm$ 0.68

a,b: Different lowercase letters indicate significant difference at  $p < 0.05$

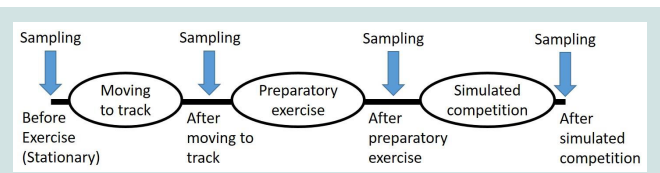
**Table 2:** Average blood lactate levels and blood cell composition (average  $\pm$  S.E.) of Hokkaido native horses at each sampling timing in Experiment 2.

	While stationary	After walking to the track	After preparatory exercise	After simulated competition
Lactate levels (mmol/L)	1.07 $\pm$ 0.07 <sup>a</sup>	1.15 $\pm$ 0.07 <sup>ab</sup>	1.38 $\pm$ 0.07 <sup>b</sup>	1.30 $\pm$ 0.07 <sup>ab</sup>
Red blood cell count (10 <sup>9</sup> / $\mu$ L)	713 $\pm$ 13.3	708 $\pm$ 13.3	724 $\pm$ 13.3	738 $\pm$ 13.3
Hemoglobin (g/dL)	10.8 $\pm$ 0.94 <sup>ab</sup>	10.0 $\pm$ 0.94 <sup>a</sup>	12.2 $\pm$ 0.94 <sup>ab</sup>	14.5 $\pm$ 0.94 <sup>b</sup>
Hematocrit (%)	41.9 $\pm$ 1.19	42.5 $\pm$ 1.19	43.9 $\pm$ 1.19	46.6 $\pm$ 1.19

a,b: Different lowercase letters indicate significant difference at  $p < 0.05$



**Figure 1:** Procedure of Experiment 1.



**Figure 2:** Procedure of Experiment 2.

across the sampling time points. Hemoglobin levels were significantly ( $p < 0.05$ ) higher after the preparatory exercise than the stationary stage.

## Discussion

Piccone et al. reported that the resting levels of blood lactate ranged from  $0.65 \pm 0.07$  to  $4.24 \pm 0.72$  mmol/L for horses of various utility, breeds, and sexes [4]. Pre-exercise lactate levels of horses in our study were all within this range. Thus, the horses used in the present study were in normal physiological condition and not fatigued before the experiment. Furthermore, Piccone et al. also reported that show jumpers exhibit a significant increase in blood lactate levels after participating in a 350 m course with eight obstacles ( $5.07 \pm 2.14$  mmol/L from  $2.26 \pm 1.18$  mmol/L pre-exercise) [5]. In Experiment 1, we also found that lactate increased significantly post-exercise ( $1.60 \pm 0.09$  mmol/L) compared with pre-exercise ( $1.20 \pm 0.09$  mmol/L). However, the rate of increase was not as great as seen in the previous study [6], indicating that the simulated competition was not a significant burden for the horses. In addition, one of the commonly used indicators of exercise intensity is “onset of blood lactate accumulation (OBLA)”, a blood lactate concentration of approximately 4 mmol/L [7]. Reaching this threshold suggests the beginning of fatigue in horses. In this study, none of the horses exceeded the onset value, indicating that they were not fatigued during the simulated competition.

Red blood cell count, hematocrit, and hemoglobin measurements are associated with the ability to transport oxygen to cells. In this study, values for all three variables—even after exercise—were close to previously reported averages of the Noma horse, another Japanese breed [8]. In contrast to an earlier study that identifies differences in blood composition between horses trained for sport versus recreation [9], this study did not observe such variation. This outcome also suggests that the horses were not overworked during our simulated competitions. Indeed, subject horses appeared to be well trained for Yabusame competitions; therefore, we conclude that the current standard for the number of runs (4-6 times) is reasonable for participating horses.

In considering the animals' welfare, this study did not examine the blood parameters of the horses in fatigue conditions. This issue is important because of the rising interest in the welfare of horses during equestrian events. In conclusion, the exercise tested in this study (simulated competition run) did not impose an excessive physiological burden on the horses, and we also clarified for the first time the physiological changes that occur while Hokkaido native horses engage in exercise-simulating mounted archery competitions.

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