

Motor ability of forelimb both on- and off-riding during walk and trot cadence of horse

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The aim of this study was to investigate the motor ability of forelimb according to on- or off-riding during cadences (walk and trot) of horse. Horses and rider selected as subject consisted of total 37 heads of Jeju native horse and 1 female rider. The variables analyzed composed of 1 stride length, 1 step length, elapsed time of stance, elapsed time of swing, elapsed time of 1 step, and forward velocity (x-axis). Two-way analysis of variance of variables was employed for the statistical analysis with the level of significance set at 5% ($P < 0.05$). Trot cadence showed significant difference with the faster and shorter during trot than that of walk in velocity and elapsed time. When analyzed interaction effect in stance and swing phase, the locomotion showed the

shorter elapsed time in trot than that of walk, but more delayed in case of on-riding during stance phase, whereas the case of on-riding showed with the shorter during swing phase than that of the case of off-riding. These results of horse's analysis meant that there was very close relation among variables of rider's weight-velocity-stride length-stride elapsed time. Next study will be necessary to analyze cadence variables added both stride length and rider's weight for riding activity and rehabilitation during horse riding using Jeju native horse.

Keywords: Motor ability, Forelimb, Riding, Cadence, Horse, Walk and trot

INTRODUCTION

The much portion of the preceded studies on horse riding composed of almost horse's cadence patterns and posture of riding because its activity always is exposed to various risk situations (Ball et al., 2007; Buckley et al., 1993; Ceroni et al., 2007; Norwood et al., 2000; Smartt and Chalmers, 2009).

Hodson et al. (2000) reported that motor ability of horse movement during walk showed 1.27 ± 0.08 sec of elapsed time for 1 stride, 1.75 ± 0.09 m of stride length, $66.2\% \pm 1.4\%$ of ratio of supporting phase (%) and 1.39 ± 0.07 m/sec of forward velocity of center of gravity (COG) when analyzed walk pattern of forelimb with various kinds of species of horse (two thoroughbreds, one quarter horse, one arabian, one morgan cross; mean weight, 477–572 kg; mean height, 143–156 cm, respectively). On the other hand, the results of walk pattern of forelimb with the same horse showed 1.71 ± 0.09 m of stride length, 1.35 ± 0.06 m/sec of forward velocity, 1.27 ± 0.07 sec of elapsed time for 1 stride, and

$65.2\% \pm 0.02\%$ of supporting phase (%) (Hodson et al., 2001). Also, Back et al. (1996) reported that trot showed shorter elapsed time of 1 stride and supporting phase (%) than that of walk, but the almost same increase ratio pattern in case of stride length and swing phase.

In the preceded study on-riding posture Quinn and Bird (1996) showed thigh angle of 30° – 40° to vertical line known as general posture pattern of lower limb during horse riding but prevented backward tilting incline at pelvic when decreased about to 20° at thigh angle with keeping shorten stirrup length to hip joint on horizontal plane. Whereas, Nicholl et al. (1991) reported the possibility that can reduce occurrence ratio of lumbar pain by keeping thigh angle over 45° .

In addition to the above, preceded studies reported the interaction effect among horse-saddle-rider (Greve and Dyson, 2013; Harman, 1999), position-transition analysis of rider during walk-trot-gallop (Lovett et al., 2005) and interaction between horse and rider (Münz et al., 2014). In recent studies, Hyun and Ryew

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Received: December 20, 2015 / Accepted: February 1, 2016

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(2015a, 2015b) reported that keeping stirrup length of 74.04% to lower limb length was more effective in stabilization and posture correction of rider. But there was no study about stride mechanism of horse according to on- or off-riding during walk and trot when reviewed the above studies about stability and effectiveness of riding posture related with motor ability of horse.

Particularly rider's capability that can move with fast velocity of 65 km on height of about 2 m from ground level with horse weight of 500 kg (Ceroni et al., 2007) also may cause another problem according to on- or off-riding (Lagarde et al., 2005). When analyzed the report that walk and trot of horse step can be most effective cadence to posture correction of rider (Ryew, 2012), motor ability of horse may be depended on ability whether transfer consistently and regularly or irregularly an action and reaction force to rider.

Therefore this study aims to obtain materials available for horse rehabilitation of the handicapped, elite rider for competitive record, trainer and life-span sports with analysis of motor ability of forelimb's movement in case of on- or off-riding during walk and trot of horse.

MATERIALS AND METHODS

Subject

Total 37 heads of Jeju native horse (mean height of withers: 1.25 ± 1.67 cm) were selected as analysis subject. Particularly the study selected only one female rider (age, 41 yr; height, 162.32 cm; body weight, 59.64 kg) over 10-yr experience because variation of skill level of horse-rider may cause difference of coordination (Lagarde et al., 2005) and error by variations of rider's body weight.

Experimental procedure

Before filming, light walking guided by two riding experts for warming up was performed during 10 min with horses selected as subject. Two cameras (HDR-HC1/HDV 1080i Handycam Camcorder, Sony, Tokyo, Japan) was set-up after alignment with horizontal (x-axis) to vertical axis (y-axis) and positioned with 1-m reference point on straight line of run way not to incline. Camera zoom lens was fully extended to capture horse's entire movement in distant range and distance (5 m) to minimize perspective error (Fig. 1) and set filming speed of 60 frames/sec with exposure time of 1/500 sec.

Definition of analysis phase

Cadence analysis divide into stance and swing phase on the basis of right fore hoof of horse (Fig. 2) according to preceded study (Hyun and Ryew, 2015c).

(a) Stance phase: from touch down (TD) to before take off (TO) on the basis of right fore hoof of horse.

(b) Swing phase: from TO of right fore hoof to TD of right hoof after stance of left hoof.

One stride means from stance of right fore hoof to touch down of left fore hoof (step: SP), and another 1 step means 1 stride+whole phase of next swing phase (stride: SE) (Fig. 2).

Data process

Motor ability during walk and trot of horse on- or off-riding during cadences was analyzed for 1 step and 1 stride using Dartfish video software solution (DFKOREA, Seoul, Korea). Variables processed composed of elapsed time of stance phase (0.0167 sec \times sample numbers), velocity (1 stride time/t) and elapsed time (%) of each phase (% per total time) respectively with Kwon 3D ver.

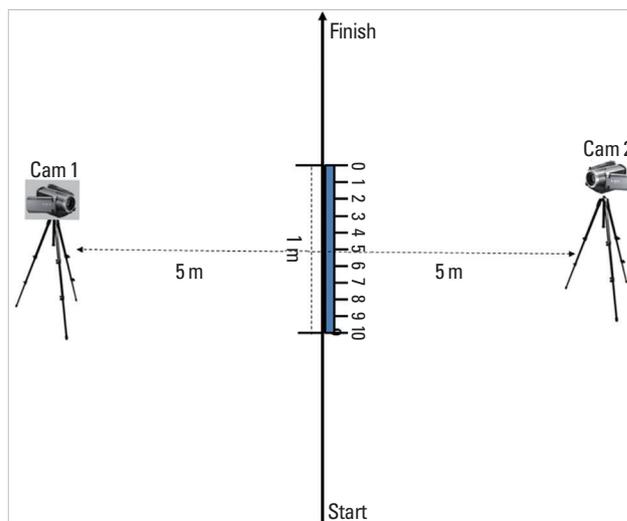


Fig. 1. Experimental field.

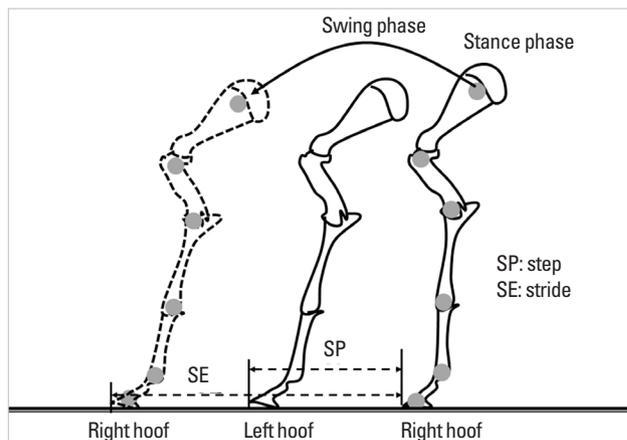


Fig. 2. Stance and swing phase (Hyun and Ryew, 2015c). SP, step; SE, stride.

3.016 (Visol, Gwangmyeong, Korea).

After two-way analysis of variance (ANOVA) of variance according to on- or off riding during quadruped cadence (walk and trot) of horse was processed when showed interaction effect ($P < 0.05$) after one-way ANOVA.

RESULTS

Change in motor ability of forelimb

The analyzed results showed each that the change in motor ability of forelimb's movement in case of on- or off riding during trot and walk of horse (Table 1), and the cadence variables of fore leg limbs of horse and relationship by times of on-riding during walk and trot (Figs. 3-8).

Elapsed time of stance phase did not show significant difference, but showed difference with the shorter in trot than that of walk cadence. Then, when analyzed the result of one-way ANOVA due to interaction effect, the elapsed time in the trot cadence of off-riding was occupied with more portion (%) during stance phase ($F = 314.009, P < 0.001$).

Elapsed time of swing phase showed significant difference with the longer in walk cadence than that of trot and showed significant difference with the longer in off-riding than that of on-riding. Then, when analyzed the result of one-way ANOVA due to

interaction effect among variables, the elapsed time in the trot cadence of on-riding was occupied with more portion (%) during swing phase ($F = 17.664, P < 0.001$).

Total elapsed time of one stride (stance+swing) did not show significant difference according to on- or off-riding, but showed significant difference with the shorter in trot than that of walk cadence.

When analyzed the result of one-way ANOVA due to interaction effect among variables, the elapsed time during one stride was occupied with more portion (%) during stance phase of trot cadence ($F = 221.494, P < 0.001$).

The forward velocity (x-axis) of horse's COG showed significant difference with the faster in off-riding than that of on-riding and showed significant difference with the faster during trot than that of walk cadence. The interaction related with the change of velocity according to cadence (walk and trot) and on- or off-riding did not show.

The length of one stride according to on- or off-riding showed significant difference with the longer in off-riding than that of on-riding, and showed significant difference with the longer in trot than that of walk cadence. The interaction for one stride according to cadence (walk and trot) and on- or off-riding did not show.

DISCUSSION

On the basis of preceded studies that can cause various negative

Table 1. Locomotion variables on forelimb according to cadence and horse riding during

Section	Cadence (C)	Horses or riding (H)		Total average	Source	F	P-value
		Horses	Horse riding				
Stance time (sec)	Walk	0.63±0.08 (64.24%)	0.60±0.07 (64.07%)	0.61±0.08	H	1.002	0.319
	Trot	0.29±0.03 (46.06%)	0.34±0.04 (53.21%)	0.32±0.04	C	925.025	0.001***
	Total average	0.46±0.18	0.47±0.14	0.46±0.16	H×C	16.001	0.001***
Swing time (sec)	Walk	0.35±0.03 (35.76%)	0.33±0.04 (35.93%)	0.34±0.04	H	29.467	0.001***
	Trot	0.34±0.03 (53.94%)	0.30±0.03 (46.79%)	0.32±0.04	C	18.568	0.001***
	Total average	0.34±0.03	0.32±0.04	0.33±0.04	H×C	4.957	0.028*
1 Stride time (sec)	Walk	0.98±0.09	0.93±0.09	0.96±0.10	H	2.521	0.115
	Trot	0.63±0.05	0.64±0.06	0.63±0.05	C	657.326	0.001***
	Total average	0.80±0.19	0.78±0.17	0.79±0.18	H×C	4.635	0.033*
Velocity (m/sec)	Walk	1.30±0.16	1.19±0.14	1.25±0.16	H	13.902	0.001***
	Trot	2.90±0.26	2.72±0.33	2.81±0.31	C	1,655.213	0.001***
	Total average	2.10±0.83	1.96±0.81	2.03±0.82	H×C	0.854	0.357
1 Step lengths (m)	Walk	0.63±0.06	0.55±0.08	0.59±0.08	H	52.18	0.001***
	Trot	0.78±0.09	0.66±0.10	0.72±0.11	C	95.537	0.001***
	Total average	0.70±0.11	0.61±0.10	0.65±0.12	H×C	2.145	0.145
1 Stride lengths (m)	Walk	1.26±0.11	1.11±0.13	1.18±0.14	H	35.842	0.001***
	Trot	1.83±0.13	1.73±0.14	1.78±0.15	C	769.81	0.001***
	Total average	1.54±0.31	1.42±0.34	1.48±0.33	H×C	1.773	0.185

Values are presented as mean ± standard deviation.

* $P < 0.05$. *** $P < 0.001$.

H, horse or riding of the main effect; C, cadence of the main effect; H×C, interaction walk and trot in horses.

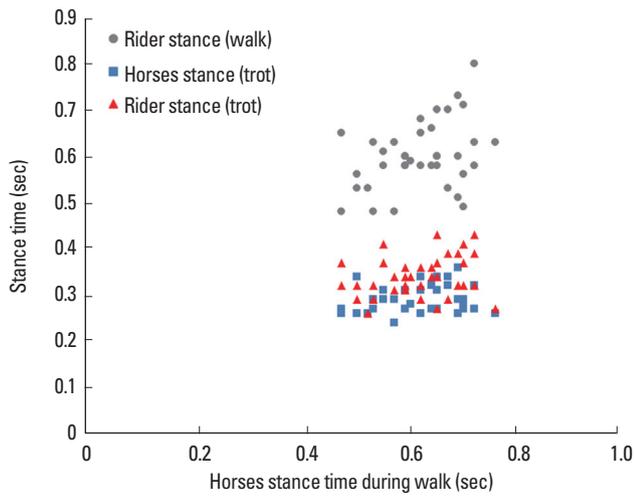


Fig. 3. Stance time variables on forelimb.

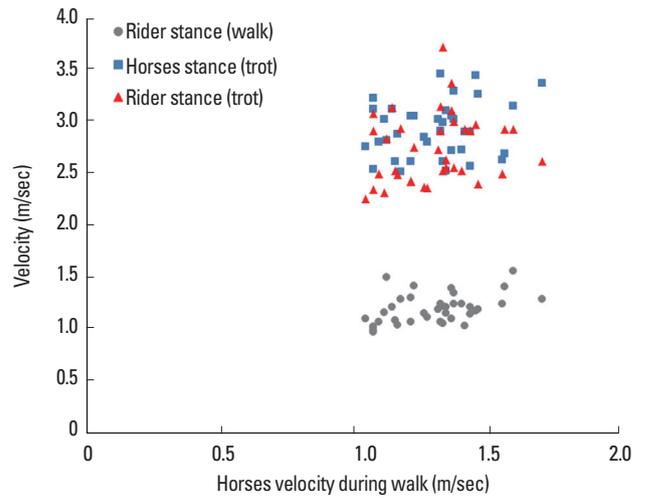


Fig. 6. Velocity variables on forelimb.

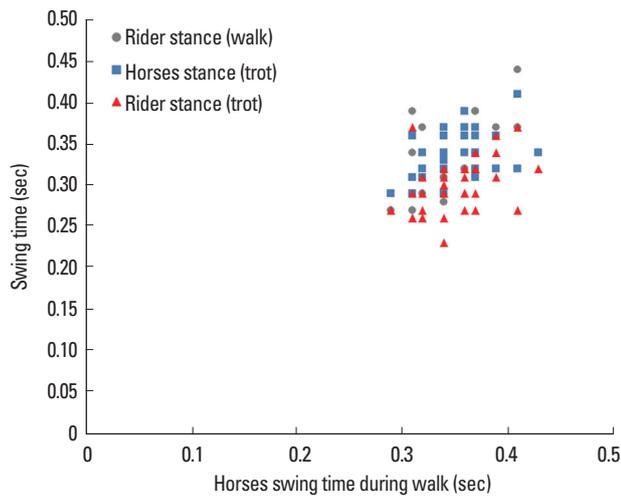


Fig. 4. Swing time variables on forelimb.

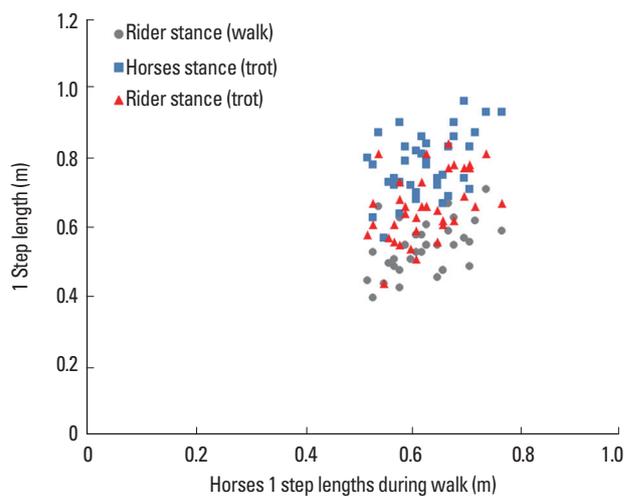


Fig. 7. One step lengths variables on forelimb.

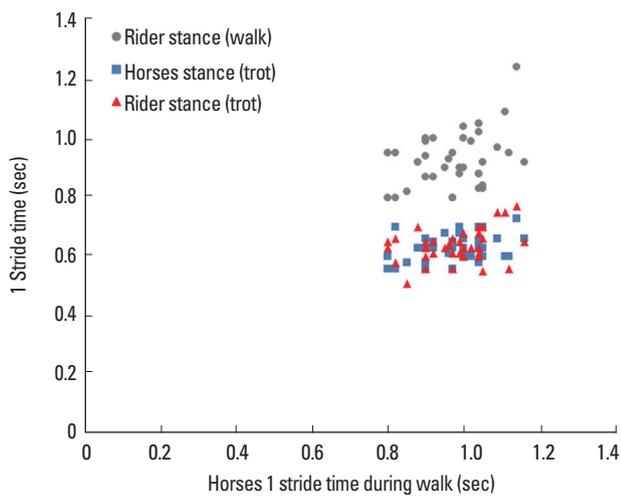


Fig. 5. Stride time variables on forelimb.

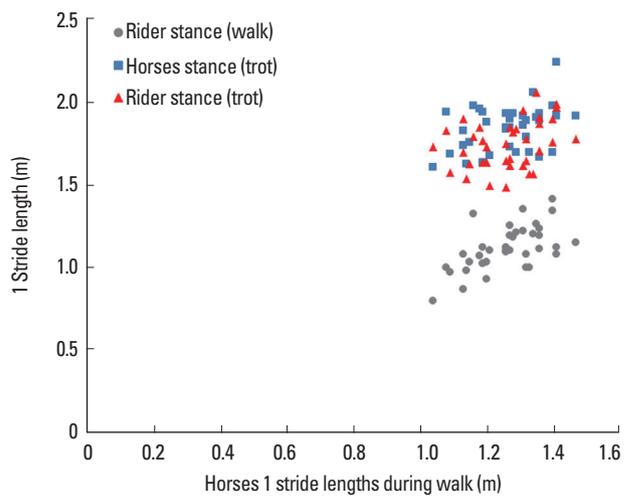


Fig. 8. One stride lengths variables on forelimb.

and positive effects when added with weight of rider on the horse (Lagarde et al., 2005), The study aimed to analyze change of motor ability of forelimb of horse according on- or off-riding during walk and trot cadence.

The result of this study showed significant difference according to cadence (walk and trot) and on- or off-riding. Also this study showed similar to result of the preceded studies, but showed significant difference in motor ability of forelimb when compared 1.30 m/sec in case of off-riding during walk of this study with mean 1.37 m/sec of Clayton (1995) and mean 1.39 m/sec from five kinds of species (two thoroughbreds, one quarter horse, one arabian, one morgan cross) of Hodson et al. (2000).

Also while mean velocity (x-axis) of COG preceded studies (Clayton et al., 2002) showed mean 1.85 m/sec similar to mean 2.90 m/sec during off-riding of this study, but showed trend of decreasing velocity of 2.72 m/sec in case of on-riding.

The quadruped cadence of horse can divide into walk cadence always remained as stance phase of two legs for one stride and trot cadence always remained as one swing phase for each stride with keeping diagonal cadence (Clayton, 2002). Jeju native horse received more downward load (weight) due to relative smaller body structure than that of thoroughbreds. Common characteristics showed more decreasing trend in forward velocity (x-axis) in two kinds of cadence in case of on-riding than that of off-riding. This study showed significant difference in elapsed time of swing and stance phase, elapsed time of one stride according to cadence (walk and trot) and the cases of on- or off-riding. That is, the case of on-riding showed more decrease of 0.08 sec in stance phase and 0.02 sec in swing phase during walk cadence with more delay of 0.04 sec, 0.05 sec respectively than in case of off-riding of this study.

Walk cadence was known to the most natural and diagonal locomotion way (Hodson et al., 2000), but this study showed more reduced ratio (%) than 66.2% of preceded study (Hodson et al., 2000) in ratio of stance phase of thoroughbreds. Also trot cadence showed less elapsed time during swing phase of 0.46 sec and stance phase of 0.93 sec in this study than that of (Clayton et al., 2002). These result influenced to velocity change (x-axis). These characteristics of horse cadence resulted from rider's weight during walk cadence may be considered as mechanism to improve motor ability through minimization of muscle contraction of forelimb during stance and swing phase. But, considering results analyzed of stance, swing phase and interaction effect during one stride in trot, horse's ability which can reduce elapsed time of stance phase might enabled to obtain dynamic stability required due to weight (horse+rider weight) added to horse during forward propulsion

phase when compared with shorter stride length than stride length of 1.75 m (Hodson et al., 2000) and 1.57 m (Clayton, 1995).

Common characteristics between two cadence (walk and trot) showed stride length of forelimb more shorten in case of on-riding than case of off-riding. These result meant that there was very close relation among rider's weight-velocity (x-axis)-stride length-stride elapsed time. Therefore next study will be necessary to analyze variables added both stride length, and rider's weight using 3-dimensional motion technique of movement pattern between horse and rider, coordination, and reaction and sitting mechanism for riding activities and rehabilitation during horse riding.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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