Comparison of Head Movement and EMG Activity of Muscles between Advanced and Novice Horseback Riders at Different Gaits

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The aim of this study was to see if differences in proficiency exist between advanced- and novice-level horseback riders with regard to head movement and EMG activity. Three advanced- and three novice horseback riders rode a horse at a walk, sitting trot and canter whilst their head acceleration and the EMG activity of their rectus abdominis muscle (M. rectus abdominis), erector spinae muscle (M. erector spinae) and abductor magnus muscle (M. adductor magnus) were recorded simultaneously. All results were conducted with Frequency Analysis by the Maximum Entropy Method. At walk, the novice rider showed a frequency distribution dispersion (P<0.1) of the head in the proximal-distal direction which was not observed in the advanced rider, but no distinct primary factors were observed in the muscular discharge frequency distributions—perhaps due to the novice rider’s level which was not completely inexperienced. At a sitting trot, unstable movements of the novice rider’s upper body were observed in the cranial-caudal direction (P<0.05), mirroring the horse’s violent rocking movements. The electromyogram frequency distributions at this gait suggest that the novice rider was unable to balance the erector spinae and rectus abdominis muscles, and therefore unable to cope with the unstable movement. It also suggests that there was instantaneous muscular activity of the adductor magnus muscle in order to stabilize the ill-balanced body. At a canter, there were no significant differences in the dispersion of acceleration frequency distribution or in the electromyogram frequency distribution, but although there were no “significant” differences, the results obtained from the advanced rider at this gait showed a dispersion of acceleration frequency distribution that was slightly greater than that of the novice rider. This situation was only observed at a canter. In conclusion, differences exist in the degree of difficulty of coordination between horse and rider according to the gait. In addition, from the results of this study, we can clearly see that differences also exist in the rider’s own skill and ability to “maintain posture”.

Key words: acceleration, coordination, electromyogram, horse, the maximum entropy method

There have been numerous publications on riding instruction and, in all these, the expression “relax” is invariably used as a basic prerequisite to making progress in riding. This expression is not only ambiguous but also abstract—in other words, perhaps it is intended to mean that as a rider acquires proficiency he becomes capable of maintaining good posture by skillful coordination with the horse’s movement “without the use of unnecessary strength” or is able to use “appropriate muscle activity”.

In recent years, equine kinetics has been analyzed by kinetic measurements with modern dynamic sensors, transducers and cameras but most of this research has focused only on the horse’s movement for the express purpose of establishing diagnostic methods for lameness and to clarify the cause of accidents [2, 3, 10, 17]. Therefore, the present situation is that whilst a few papers have been submitted regarding studies conducted on the movements of the mounted horse [1, 4–6, 8, 9, 11, 12, 16], there have been hardly any regarding the rider. Therefore, the aim of this study was to confirm if

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differences exist in the degree of the rider’s ability to “maintain posture”, which is thought to be a basic prerequisite to riding progress. Thus a comparative study of the relationship of the advanced and novice rider was conducted with regard to riding posture and muscle activity. For the purpose of obtaining some clues as to “appropriate muscle activity” measurements were taken with an electromyogram.

Materials and Methods

The subjects of this study were 3 riders with 1 year or less riding experience (novice rider, Mean weight ± s.d. was 53 ± 1.5 kg) and 3 riders who are qualified to compete in all Japan’s student competitions (advanced riders, Mean weight ± s.d. was 51 ± 2.6 kg). From these, 2 advanced riders and 2 novice riders (for a total of 4 subjects), took it in turns to ride one of the experiment horses, and the remaining advanced rider and novice rider (a total of 2), took it in turns to ride the other horse, twice over the approximately 80-metre long course at the 3 gaits: the walk, the sitting trot and the canter. The subjects were instructed to refrain as much as possible from using aids or taking action to control the movement of the horse.

A VTR camera (Handycam video Hi8, Sony, Tokyo Japan), was used to record and measure the duration time of one stride in each gait during the trial runs.

For head-movement recordings, accelerometers (Multi telemeter system, measurement range ± 25 G, Nihon Kohden Corp, Tokyo, Japan) were installed in the vertex part of the helmets worn by the riders. The directions of the accelerometers were the proximal-distal and the cranial-caudal.

To check the rider’s sitting posture, the rectus abdominis muscle (M. rectus abdominis), erector spinae muscle (M. erector spinae) and adductor magnus muscle (M. adductor magnus) were selected and recorded electromyographically. The electrodes used were disposable surface electrodes (Multi telemeter system, Nihon Kohden Corp, Tokyo, Japan) (Fig. 1). On the rectus abdominis muscle, disposable surface electrodes were attached 2 cm below the umbilicus; on the erector spinae muscle they were attached to the symmetrical points of the rectus abdominis muscle; and on the adductor magnus muscle the electrodes were attached 10 cm below the crotch. The EMG of each muscle was recorded with a bipolar system and the distance between these bipolar electrodes was 2 cm. At this point, the electrodes in connection with the adductor magnus muscle were covered with special pads to eliminate the possibility of erroneous results due to direct contact between the electrodes and the saddle.

Data analysis

Samples of the measured acceleration data and electromyogram data were made at 1 KHz for each of the runs in approximately a 5-stride period, and a frequency analysis of each was made by the Maximum Entropy Method (MemCalc system Ver. 2.5, GMC Inc,

Fig. 1. Measurement item and experiment method.
The duration time of one stride in each gait was calculated from the VTR images and then converted to the frequency values.

The dispersion of the acceleration frequency band distribution obtained from the head at a walk and at a canter was converted into numerical values for {other than the (peak frequency + sub-peak frequency)}/(peak frequency + sub-peak frequency)}(hereinafter referred to as dispersion value). At a sitting trot the dispersion value was calculated by finding the frequency band component of (other than the peak frequency band)/peak frequency band). After each dispersion value was calculated from the measurement results of each of the subject’s 2 runs, the mean dispersion values were calculated from the 2 runs, and these mean values were used to conduct a t-test of the advanced rider and the novice rider.

The electromyogram spectrum data obtained from the frequency analysis were divided into three gradations: low frequency band (5–45 Hz), intermediate frequency band (46–80 Hz) and high frequency band (equal to or more than 81 Hz spectrum) [13]. Each gradation rate was calculated from the measurement results of each subject’s 2 runs, and then the mean gradation rates for the advanced rider and the novice rider were calculated from the measurement results of the six runs (2 runs × 3 riders) that were conducted for each level.

Results

1) The frequency value of one cycle

The frequency values ranged between 0.75 and 0.98 Hz at a walk; 1.17 and 1.43 Hz at a sitting trot; and 1.53 and 1.82 Hz at a canter.

2) The acceleration analysis

Figure 2 shows a typical result for acceleration frequency, and the dispersion values are indicated in Table 1.

At a sitting trot a significant difference (P<0.05) was observed in the cranial-caudal direction which was not observed in the proximal-distal direction.

At a canter no significant difference was observed between the advanced rider and the novice rider in either the proximal-distal or cranial-caudal directions.

3) Electromyogram analysis

Figure 3 shows a graph which indicates the rates for each low, intermediate and high frequency band in the 5 Hz or more of the subject muscles’ electromyogram.

At a walk, when a comparison was made of the low, intermediate and high frequency rates, a high intermediate frequency band rate was observed in the novice rider, especially in the erector spinae muscle. This was in contrast with the advanced rider where the frequency bands of these 3 muscles indicated similar muscle activity. But in the high frequency band, the advanced rider’s activity rate was greater than that of the novice rider for all the muscles.

By observing the frequency distribution during the sitting trot, in the advanced rider, the rectus abdominis and erector spinae muscle indicated similar activity and the adductor magnus muscle indicated hardly any activity, whereas in the novice rider, the rectus abdominis and erector spinae muscle did not indicate similar muscle activity and in the adductor magnus muscle, the rate of intermediate and high frequency bands was higher than in the advanced rider.

At a canter, there were no obvious differences between the novice rider and the advanced rider in any of the target muscles.

Discussion

The accelerometer has hitherto been widely used for the purpose of measuring the maintenance of an erect position [13]. Further, as the vertex part of the human body has been considered to be especially affected by jostling movements, so the vertex part has attracted special attention as a measurement site.

It is extremely important for a rider in equestrian competition to maintain good posture. The posture of the mounted rider is not an erect position, but the vertex part of the rider is the still site which is most affected by the shaking of the body. In view of this, this site was selected in this study because the acceleration measurement value for the rider’s head is an indicator of the rider’s ability to maintain the correct posture.

In observing frequency band by band, the low frequency band component is the muscle power displayed in order to conduct static movement, the
high frequency band component is the muscle power displayed in order to conduct principally kinetic movement and the intermediate frequency band component plays the role of being affiliated with both the static and kinetic movements [13].

The erector spinae muscle was selected as a subject muscle for this study because it is the muscle which maintains posture. The rectus abdominis muscle was selected because it is erector spinae's antagonist muscle, and therefore contributes to, whilst not being

Fig. 2. Frequency distribution of acceleration at rider's head.
primarily responsible for maintaining posture. Although the adductor magnus muscle was not originally considered to be a posture-maintaining muscle, because it is said that the leg is used for aids on the horse. But since the subject riders in this study were instructed “not to use leg aids on the horse”, this muscle was classified as a posture maintaining muscle because it tightens around the horse’s body to maintain posture. And the results for the adductor magnus muscles observed in this study show muscle activity in the intermediate and high frequency bands, indicating that this muscle also contributes to posture maintenance.

The equine kinetics at a walk are more complex than they may seem, involving twisting of the vertebra, “At a walk, twisting was more dominant in comparison to the other gaits” [7]. The horse moves forward at 4 beats, but, as the left and right movements are symmetrical, this actually is a repetitive forward movement of 2 up and down movements. For this reason, we use (other than the (peak frequency + sub-peak frequency)/(peak frequency + sub-peak frequency)) to calculate the dispersion value of the acceleration frequency at a walk. In the dispersion value of the acceleration frequency in the proximal-distal direction of the subjects of this study, a significant difference (P<0.1) was observed between the novice rider and the advanced rider, and there was very little dispersion in the advanced rider when compared with the novice rider at a walk. The fact that the acceleration frequency was concentrated in the (peak frequency value + sub-peak frequency) meant that the head movement variation did not change for every stride in the advanced rider. It is thought that this was possible because the rider gauged the horse’s movement and, to cope with it, instigated the corresponding muscle activity. However, during a walk, the results of the electromyogram analysis showed a higher level of frequency activity in all subject muscles

| Table 1. Dispersion value of acceleration at rider’s head |
|---|---|---|---|---|
| Walk | Proximal-distal | ID | A | B | C | average | 
| Novice | 5.52 | 6.50 | 3.72 | 5.91 |  |  
| Advanced | 3.91 | 4.69 | 5.18 | 4.59 |  |  
| Cranial-caudal | ID | A | B | C | average |
| Novice | 6.46 | 6.08 | 8.22 | 6.92 |
| ID | D | E | F | average |
| Advanced | 6.03 | 3.87 | 10.56 | 6.82 |
| Sitting trot | Proximal-distal | ID | A | B | C | average |
| Novice | 4.32 | 4.13 | 6.00 | 4.82 |
| Advanced | 4.56 | 5.55 | 4.53 | 4.88 |
| Cranial-caudal | ID | A | B | C | average |
| Novice | 8.26 | 8.74 | 10.81 | 9.27 |
| ID | D | E | F | average |
| Advanced | 3.96 | 4.96 | 4.70 | 4.54 |
| Canter | Proximal-distal | ID | A | B | C | average |
| Novice | 2.82 | 3.43 | 6.91 | 4.39 |
| Advanced | 3.76 | 4.64 | 6.48 | 4.96 |
| Cranial-caudal | ID | A | B | C | average |
| Novice | 4.51 | 4.31 | 8.88 | 5.90 |
| ID | D | E | F | average |
| Advanced | 6.13 | 4.23 | 8.34 | 6.23 |

†=P<0.1. ††=P<0.05.
of the advanced rider than in the novice rider, as well as a large amount of intermediate frequency in the erector spinae muscle of the novice rider. These results make it difficult to arrive at a conclusion concerning the cause of the jostling of the head of the novice rider in the proximal-distal direction. As the novice riders used in this study were subjects who were able to conduct canter gait by themselves, this is thought to be why very little difference arose in the walk. In order to observe these differences in the future, it would be necessary to use completely inexperienced riders.

"The trot is a two-time gait (Two hoof-beats). There are two steps to a stride, the sequence of hooffalls being: 1 left-fore and right-hind together (left diagonal). 2 Right-fore and left-hind together (right diagonal). There is a brief moment of suspension between each step." [14]. That is to say, the horse moves forward at 2 beats but, since the left and right movement and also the fore-and hind-limb movement are symmetrical, this is actually one repetitive up-and-down forward movement. For this reason, we use other than the peak frequency band/peak frequency band to calculate the dispersion value of the acceleration frequency at a sitting trot. According to these results, there was more significant dispersion (P<0.05) in the distribution of acceleration frequency in the cranial-caudal direction of the vertex part in the novice rider than in the advanced rider. The fact that the acceleration wave was not concentrated in the peak frequency value means that the head variation of the rider changes every stride. It suggests that the novice rider was unable to coordinate himself with the cranial-caudal movement of the horse body and therefore portrayed the observed unstable movement. And it is known from that therefore, that the novice rider found it difficult to stay in balance with the motions of the horse. Further, it is thought that this occurred because the rider was unable to gauge the movement of the horse and did not instigate the necessary muscle activity to cope with it.

In observing the electromyogram frequency band distribution of the novice rider at that moment, frequency differences were observed in the erector spinae muscle and its antagonist muscle, the rectus abdominis muscle. This was in contrast with the advanced rider where these 2 muscles indicated similar frequency distributions. And in the novice rider, kinetic activity (the rate of intermediate and high frequency bands) was observed in the adductor magnus muscle in contrast with the advanced rider where almost no kinetic activity was observed. In the novice rider, this was presumed to be a sign that the rider attempted to compensate for the unbalanced upper body by using the muscle power of the adductor magnus muscle, and the resulting dispersion of the acceleration frequency of the novice rider’s head in the cranial-caudal direction was because the rider was unable to correctly gauge the movement of the horse.

Fig. 3. The frequency rate of the electromyogram of three muscles at walk, sitting trot and canter: a) the rectus abdominis muscle and b) the erector spinae muscle and c) the adductor magnus muscle.
and thus not able to instigate activity to balance the erector spinae and rectus abdominis muscles and cope with the situation. But since the electromyogram data was necessarily affected by individual characteristics, I would like to go on to develop these experiments with additional riders.

In 1994, Galloux et al. reported “The pitching rotation was most marked at the canter” [7]. Because of this pitching movement, the canter seems like a 2-beat movement and it is therefore reasonable to calculate the acceleration frequency band distribution from (other than the (peak frequency + sub-peak frequency)/(peak frequency + sub-peak frequency)) in spite of the fact that the horse moves forward at 3 beats. As a result, no significant difference in the degree of riding ability was observed in the acceleration in the proximal-distal direction or the cranial-caudal direction. This was due to the fact that the pitching movement of the horse at canter causes fewer jostling movements than when at a sitting trot, making adjusting to the canter relatively easier—even for the novice rider. Nevertheless, although differences in head acceleration in the canter were not “significant”, the results did show that the frequency concentrate slightly less in the (peak frequency + sub-peak frequency) value for the advanced rider than for the novice rider. This situation did not occur at the other gaits. In considering the “untimely rider’s movement which affects the latitude of the center of gravity which increases the latitude of the horse’s center of gravity in mid-air” [15], and there were no obvious differences between the novice rider and the advanced rider in any of the target muscles, this particular type of acceleration dispersion of the advanced rider may be the result of the rider’s involuntary effort to control the movement of the horse.

In conclusion, differences exist in the degree of difficulty of coordination between the horse and the rider according to the gait. We can also see from the results of this study that differences also exist in the rider’s ability to “maintain posture” according to his degree of skill. Furthermore, inappropriate muscle activity has been pointed out as one of the causes of acceleration frequency dispersion of the vertex part during the sitting trot.

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References


