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Dressage training affects temporal variables in transitions between trot and halt

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Abstract

The gaits of the dressage horse have been described, but less information is available regarding the transitions between gaits. The objective was to describe and compare temporal variables during transitions from trot to halt (TH) and halt to trot (HT) in horses competing in different levels of dressage competitions. The experimental hypothesis was that a higher level of training is associated with the ability to make more direct transitions with fewer non-trot steps. Video recordings of TH and HT transitions were made during novice ($n = 15$ horses), medium ($n = 15$ horses) and advanced ($n = 15$ horses) dressage competitions and were analysed to determine the timing of footfalls and lift-offs. Duty factors, diagonal dissociations and suspension durations were calculated for eight diagonal steps preceding and following the halt. The steps were classified as trot or non-trot based on diagonal synchrony of the footfalls. Statistical analysis using a general linear model ANOVA with Tukey B *post hoc* tests indicated that advanced horses changed their limb coordination patterns more abruptly, and that they maintained positive diagonal dissociation and a suspension phase in the steps in closer proximity to the halt than the novice horses. There was no preference between left/right and fore/hind limbs in the order of limb placements in the TH transition. The first limb to move off from the halt was always a forelimb, with a significant preference for the right forelimb in the advanced horses.

Keywords: gait; kinematics; limb coordination; transition

Introduction

Quadrupedal mammals vary the temporal and spatial coordination of their limb movements to perform different gaits. Limb movements are thought to be generated and controlled by central pattern generators, which are intraspinal networks of neurons capable of producing rhythmic flexions and extensions of the joints that result in limb movement and determine the coordination patterns between the left and right, forelimbs and hind limbs that are characteristic of the different gaits[1]. Horses are particularly versatile in the range of gaits they perform[2–4]. Most equine gait research has focused on steady-state locomotion in a specific gait. For example, in dressage horses, temporal and spatial kinematics have been described for the walk[5], trot[6–9] and canter[10]. There have been relatively few studies of transitions[11,12]. Horses perform transitions between gaits from a very early age in accordance with the need to move at different speeds. The trigger for natural transitions is controversial. Theories include the idea that a transition occurs when a gait reaches its mechanical limit[13] or that transitions are used to reduce the metabolic cost of locomotion[14] or musculoskeletal loading[15].

Transitions performed in the sport of dressage differ from transitions performed naturally: the trigger is a learned cue from the rider. Ideally, the gait before and after the transition is performed at steady state, i.e. without changing speed or stride rate in preparation for the transition. Under these conditions, the mechanical or metabolic stimuli that drive natural

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transitions are overridden by the trained response. Dressage training emphasizes the importance of transitions between and within the gaits both for improving the quality of the overall performance as well as for maximizing scores awarded in competition for the quality and precision of the transitions *per se*. One of the desirable qualities of a transition between gaits is that the horse moves directly from one gait to the other without the intervention of intermediate steps that are not characteristic of the footfall pattern or limb support sequence of either gait[11]. The expectation of a horse's ability to perform transitions without intermediate steps increases with level of training.

In the early stages of dressage training, transitions are performed between gaits that are adjacent on the speed continuum (halt and walk, walk and trot, trot and canter). As training progresses, horses perform transitions between gaits that are not adjacent on the speed continuum and that have larger speed differentials, such as trot and halt. In the trot, limb movements are synchronized by diagonal pairs, although there is often a small dissociation between diagonal contacts and lift-offs[6,8,9,16], with either the forelimb or hind limb contacting the ground earlier.

Transitions from trot to halt (TH) and from halt to trot (HT) are performed at all levels of dressage competition. Ideally, in the TH transition, the diagonal limb synchronization pattern is maintained through the transition, with adjustment of step lengths to bring the contralateral limb pairs into alignment in a square halt. When moving off from HT, the horse should immediately step off with a diagonal limb synchronization pattern. Previous studies have shown that transitions between walk and trot are made with fewer intermediate steps in horses trained to a higher level in dressage[11]. Interestingly, the ability to perform direct transitions between trot and canter did not change with level of training, which may reflect the fact that there are fewer limb coordination options when changing between the symmetrical diagonal limb coordination pattern of trot and the asymmetrical pattern of canter in which movements of one of the diagonal limb pairs are synchronized[12].

This study was designed to describe and compare temporal characteristics of the TH and HT transitions in horses performing in different levels of dressage competitions. The experimental hypothesis is that horses competing at a higher level will perform the transitions more directly, with fewer non-trot steps.

Materials and methods

The experimental protocol was approved by the institutional committee for animal care and use.

Data collection

Video recordings (60 Hz) using a Sony Handycam DCR-HC32 (Sony Corporation, Tokyo, Japan) were made at a dressage show sanctioned by the United States Dressage Federation during competitions at training level in which the halt is approached in working trot (novice; $n = 15$) and second level in which the halt is approached in collected trot (medium; $n = 15$). Recordings were made using a Panasonic AG450 Super VHS camcorder (Matsushita Electric Corp. of America, Secaucus, NJ, USA) at the Barcelona Olympic Games during performance of the Grand Prix test in which the halt is approached in collected trot (advanced; $n = 15$). Each horse was evaluated in one competition only. Riders gave written consent for the use of their videos. During each competition, the camera was set up in an appropriate place to allow good visualization of limb movements in the TH and HT transitions.

Data analysis

The videotapes were viewed in slow motion using TeamPro software v 4.5 (Dartfish, Alpharetta, GA, USA). This software allows frame-by-frame replay forwards and backwards and image magnification. The hard arena base was covered with approximately 6 cm sand at both locations. Contact between the hoof and sand was easily identified, but the presence of the sand prevented visualization of hoof contact with the underlying base. Therefore, as in other studies (e.g. Clayton[8,10]), stance duration was measured according to hoof contact with the sand. For the TH transitions, the last limb to become stationary was noted and the preceding eight diagonal steps (four strides) were analysed. These steps were named TH8–TH1, with TH1 being the step immediately preceding the halt. For the HT transition, the first limb to move forward defined the end of the halt. This limb was noted and the following eight diagonal steps (four strides) were analysed. These steps were named HT1–HT8, with HT1 being the step immediately after the halt. This follows the convention of naming the strides from the event of interest outwards, for example during analysis of jumping when the jump is the event of interest[17,18].

The temporal analysis was performed on a frame-by-frame basis to determine contact and lift-off times of each hoof. Contact was defined as the first frame in which the hoof had visible contact with the sand footing, and lift-off was the first frame in which there was no visible contact between the hoof and the footing. The following temporal variables were measured:

Duty factor of each limb was calculated as stance duration (time elapsing between contact and lift-off)

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divided by the sum of the stance and swing durations (time elapsing between lift-off and the subsequent contact) for that limb.

Diagonal dissociation at contact was the time elapsing between contacts of a diagonal pair of hooves, with a positive value being assigned if hind contact preceded fore contact and a negative value being assigned if fore contact preceded hind contact.

Diagonal dissociation at lift-off was the time elapsing between lift-offs of a diagonal pair of hooves, with a positive value being assigned if hind lift-off preceded fore lift-off and a negative value being assigned if fore lift-off preceded hind lift-off.

Suspension was the aerial phase between successive diagonal stance phases, when none of the hooves was in contact with the ground. It was calculated as the time elapsing between lift-off of the last hoof of a diagonal pair until contact of the first hoof of the next diagonal pair.

The steps were classified as trot or non-trot based on the amount of diagonal dissociation at contact. Trotting dressage horses frequently show diagonal dissociation at contact of the order of 0.03 s[9], which is below the threshold for perception by the human eye. For this study, steps with absolute diagonal dissociations at contact <0.1 s were regarded as having a diagonal coordination pattern and were classified as trot steps, whereas steps with absolute values of diagonal dissociations at contact >0.1 s were designated as non-trot steps. On this basis, each diagonal pair of footfalls was categorized as a trot step or a non-trot step. The halt was defined as a period of time during which all of the hooves were in contact with the ground.

Statistical analysis

Descriptive statistics (mean ± SD) were calculated for the measured variables during the eight steps of the TH and HT transitions. Within each type of transition, differences between levels of training (novice, medium and advanced) were sought using the general linear ANOVA model (SAS Institute Inc., Cary, NC, USA). When differences were present, the Tukey B *post hoc* test was used to determine where the differences lay. Contingency tables and a χ^2-test were used to detect differences between levels of training in the number of horses that were trotting in the steps preceding and following the halt. Preferences for initiating and completing the halt with a left or right limb and with a fore- or hind limb were analysed using an χ^2-test for equality of distribution. All statistical tests were performed using a probability of $P < 0.05$.

Results

TH transitions

The diagonal synchrony of the limb movements was maintained in all horses through step TH4 (Fig. 1). Within each group, one or two horses lost the diagonal synchrony and showed non-trot steps in step TH3, and by step TH1 the number had increased to 6 horses in the advanced group, 14 horses in the medium group and 11 horses in the novice group. The number of horses that were trotting differed significantly between groups in step TH1.

Mean values for the diagonal dissociations at contact and lift-off were slightly positive in all groups during steps TH8–TH6, but became negative in the novice horses in step TH5 and in the medium and advanced horses in step TH2. All groups had negative values for diagonal dissociation at both contact and lift-off in steps TH2 and TH1 (Table 1).

In both the forelimbs and hind limbs duty factors increased with proximity to the halt (Fig. 2). The values were significantly larger in the novice group than in the advanced group from TH8 to TH3 for all except one step. Mean values for the medium group lay between those of the novice and advanced groups. Duty factors increased markedly in steps TH2 and TH1, and there were no differences between groups for these steps.

In step TH8, only the advanced group had a suspension phase; the mean value for suspension was zero in the medium group and negative in the novice group; a negative value indicates overlap between successive diagonal stance phases (Table 1). In subsequent steps, the amount of overlap increased progressively and more rapidly in the novice group than in the medium group. Horses in the advanced group retained a suspension phase until TH4, after which there was a rapid increase in the amount of overlap in steps TH3–TH1. Duration of the suspension phase differed significantly between the novice and advanced horses in all steps, except TH1 in which all groups showed an overlap of >0.5 s as a consequence of the fact that the limbs of the other diagonal had already halted (Table 1).

For horses in the novice group, the first limb to step into the halt was more often a hind limb and the last limb to step into the halt was more often a forelimb (Table 2). There was no left/right preference in any group with regard to the first or last limb to halt (Table 3).

HT transitions

The first limb to step out of the halt was always a forelimb, and preference for using a forelimb was significant in all groups (Table 2). The first limb to step forward was the left forelimb in 14 horses and the

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right forelimb in 31 horses. Horses in the advanced group showed a significant preference to move off with the right rather than the left forelimb (Table 3).

All horses in the advanced group and 12 horses in the medium group were already trotting by step HT3, compared with only 2 horses in the novice group, and it was not until step HT7 that all novice horses had established the diagonal coordination pattern of the trot. The number of horses that were trotting differed significantly between groups in steps HT3 and HT4.

Diagonal dissociations at contact and lift-off were negative in all groups in steps HT1–HT4 (Table 4). Diagonal dissociation at contact became positive in steps HT3, HT5 and HT7 in the advanced, medium and novice groups, respectively. Values at contact were significantly larger in the advanced group than in the novice group in steps HT2–HT8. Diagonal dissociation at lift-off became positive in the advanced group in step HT5 and in the medium and novice groups in step HT7. Significant between-group differences in diagonal dissociation at lift-off disappeared by step HT6 (Table 4).

Fore and hind duty factors decreased progressively in the steps following the move off from the halt (Fig. 2). The values were significantly larger for horses in the novice group than the advanced group for all steps in the forelimb and for step HT3 onwards in the hind limb.

Suspension was present in the advanced group from step HT4 onwards, but was not present in any step in the other two groups. The values differed significantly between the novice and advanced groups in all eight steps, and there was significantly less overlap in horses in the medium group than in the novice group in steps HT1–HT5 (Table 4).

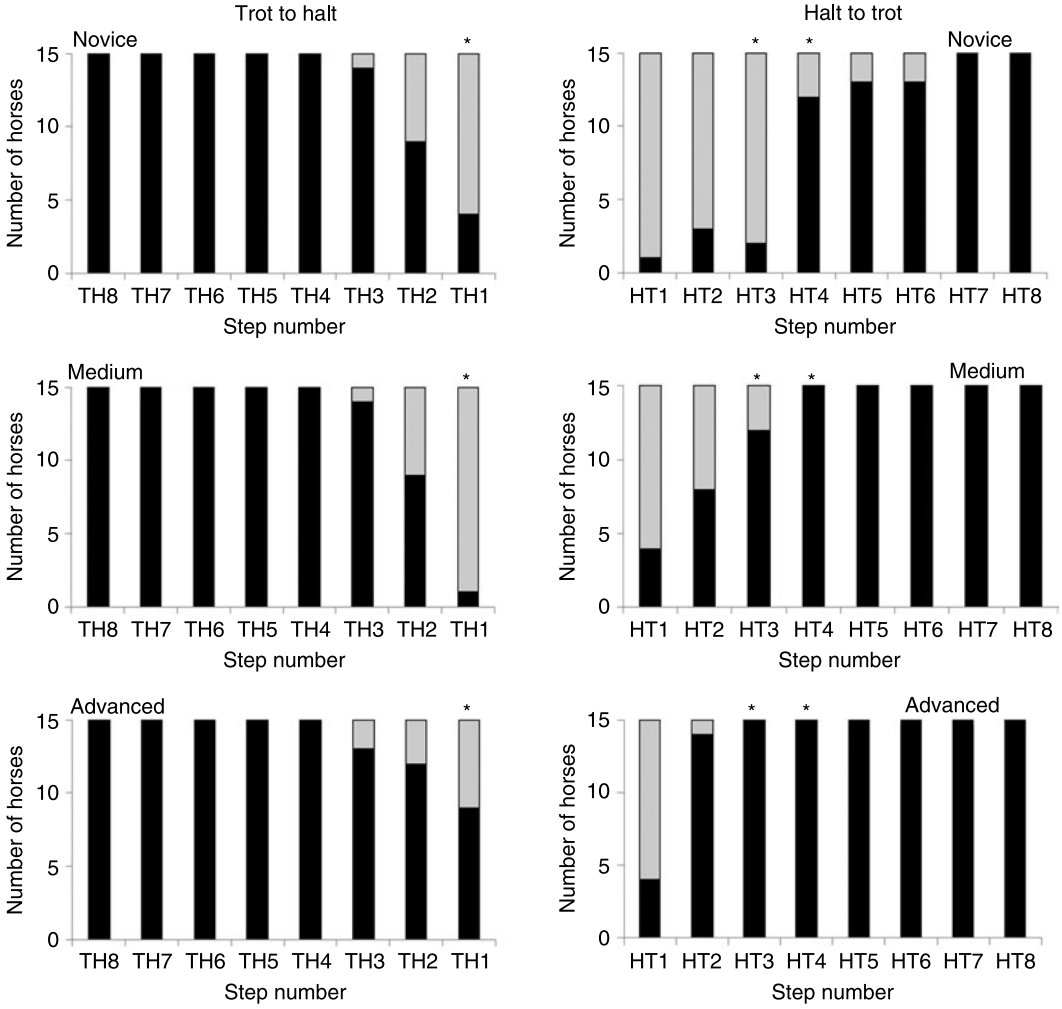


FIG. 1 Number of horses in which the steps are diagonally synchronized defined by having diagonal dissociation at contact <0.01 s (black shading) and number of horses in which diagonal dissociation at contact is >0.1 s (grey bars) in the eight steps preceding the transition from trot to halt (left panel) and in the eight steps following the transition from halt to trot (right panel) for horses competing at novice (top), medium (middle) and advanced (below) levels of competition. Asterisks indicate values that differ between levels of training

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Table 1 Diagonal dissociation at contact, diagonal dissociation at lift-off and duration of suspension for the last eight steps of a transition from trot to halt for novice, medium- and advanced-level dressage horses

	Diagonal dissociation at contact (s)			Diagonal dissociation at lift-off (s)			Suspension (s)		
Step	Novice	Medium	Advanced	Novice	Medium	Advanced	Novice	Medium	Advanced
TH8	0.02^{a} (0.02)	0.01^{a} (0.03)	0.03^{a} (0.03)	0.02^{a} (0.01)	0.00^{a} (0.03)	0.01^{a} (0.04)	− 0.02^{a} (0.04)	0.00^{a} (0.04)	0.04^{b} (0.06)
TH7	0.00^{a} (0.03)	0.01^{a} (0.03)	0.03^{b} (0.05)	0.01^{a} (0.02)	0.02^{a} (0.03)	0.01^{a} (0.04)	− 0.04^{a} (0.04)	− 0.01^{a,b} (0.04)	0.01^{b} (0.07)
TH6	0.02^{a} (0.04)	0.01^{a} (0.04)	0.04^{a} (0.04)	0.00^{a} (0.03)	0.01^{a,b} (0.03)	0.03^{b} (0.03)	− 0.03^{a} (0.05)	− 0.01^{a,b} (0.03)	0.06^{b} (0.05)
TH5	− 0.01^{a} (0.01)	0.01^{a,b} (0.02)	0.02^{b} (0.03)	− 0.02^{a} (0.07)	0.01^{a} (0.03)	0.02^{a} (0.02)	− 0.09^{a} (0.10)	− 0.02^{b} (0.03)	0.09^{c} (0.04)
TH4	0.01^{a} (0.04)	0.01^{a,b} (0.03)	0.04^{b} (0.05)	− 0.07^{a} (0.12)	0.00^{b} (0.04)	0.03^{b} (0.02)	− 0.14^{a} (0.15)	− 0.05^{b} (0.05)	0.04^{c} (0.06)
TH3	− 0.04^{a} (0.09)	0.01^{a} (0.04)	0.01^{a} (0.06)	− 0.19^{a} (0.19)	− 0.08^{b} (0.07)	− 0.07^{b} (0.14)	− 0.35^{a} (0.25)	− 0.18^{b} (0.12)	− 0.10^{b} (0.21)
TH2	− 0.05^{a} (0.13)	− 0.03^{a} (0.06)	− 0.02^{a} (0.09)	− 0.21^{a} (0.18)	− 0.16^{a} (0.16)	− 0.09^{a} (0.13)	− 0.46^{a} (0.243)	− 0.40^{a,b} (0.20)	− 0.26^{b} (0.20)
TH1	− 0.21^{a} (0.15)	− 0.06^{b} (0.10)	− 0.10^{b} (0.11)	− 0.06^{a} (0.08)	− 0.16^{a} (0.34)	− 0.21^{a} (0.21)	− 0.50^{a} (0.53)	− 0.68^{a} (0.32)	− 0.53^{a} (0.27)

Step 8 is the final step into the halt. A negative value for suspension indicates the amount of overlap between diagonal stance phases. Within each variable, values with the same superscripts across a row do not differ significantly between levels of training ($P < 0.05$).

Discussion

The results of this study support the experimental hypothesis that horses performing at a higher competitive level perform transitions from TH and HT more directly based on the smaller number of non-trot steps during the transitions and on the ability to retain the temporal variables of the trot in the steps approaching the halt and to re-establish them in the steps following the move off from the halt. This finding agrees with the results of a previous study in which the ability of dressage horses to perform direct transitions from walk to trot and from trot to walk without the intervention of intermediate steps improved with the horse's level of training[11]. The ability to make direct transitions requires the development of both motor coordination and muscular strength. In the early months of training under saddle, sport horses show a reduction in hind limb stance duration[19] that is interpreted as being a response to the development of increased strength in the propulsive muscles that allow the necessary impulses to be generated in a shorter stance time. The lower-duty factors recorded in our study for horses in the medium and advanced groups suggest that strength enhancements had continued in these horses through a prolonged period of dressage training. The increase in duty factors in the steps approaching the halt was expected as a consequence of the reduction in speed[8].

The method of determining hoof contact and lift-off times affects the values for duty factors and suspension. It is estimated that hoof contact with the sand occurred up to one video field (0.017 s) earlier than contact with the underlying base, and loss of hoof contact with the sand occurred up to 0.017 s later than lift-off from the base. Therefore, using hoof contact with the sand to determine contact and lift-off biases the results such that duty factors tend to be overestimated and suspensions tend to be underestimated. This may explain the apparent lack of a suspension phase in the novice and medium groups. The benefits of using hoof contact with the sand to determine stance are that it is easy to distinguish visually and it facilitates direct comparison with previous kinematic studies of the trot of dressage horses that were based on the same methodology[8].

The suspension phase in the trot occurs as a result of the limbs exerting an average vertical ground reaction force in the stance phase that exceeds the horse's body weight. The larger the vertical impulse, the higher and longer the suspension. In dressage horses a long suspension phase is regarded as a positive attribute, and duration of the suspension increases progressively from collected to working, medium and extended trots[8]. Individual horses vary in their ability to generate high vertical forces. For example, trotting

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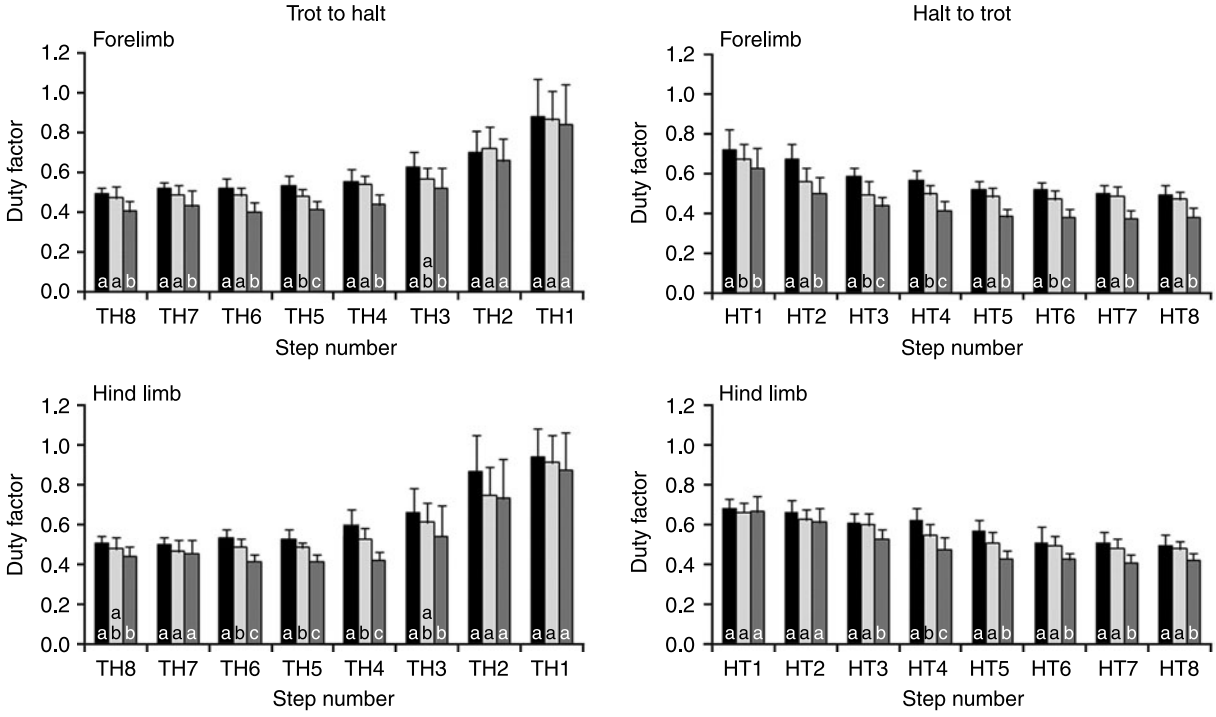


Fig. 2 Duty factors in the eight steps preceding the trot to halt transition (left panel) and the eight steps following the move off from the halt into the trot (right panel). Values are mean and SD for the left and right forelimbs (above) and mean and SD for the left and right hind limbs (below) for horses competing at novice (black bars), medium (light grey bars) and advanced (dark grey bars) levels of competition. Different letters within the bars indicate values that differ significantly for the three levels of training within the same step

Quarter Horses have lower peak vertical forces normalized to body mass than warmbloods[20]. Overall, the advanced horses had the longest suspensions that may have been a consequence of the development of greater muscular strength as a corollary of prolonged dressage training. In the steps of the TH transition, duration of suspension decreased, and the suspension was eventually replaced by a period of overlap in the strides preceding the halt. We speculate that this was achieved by modulating the force developed in the fibres of the superficial digital flexor muscle to soften the musculotendinous spring that supports the fetlock, thus reducing elastic recoil in the later part of stance. This is similar to the mechanism by which the biceps brachii regulates speed during locomotion at faster speeds[21]. The propulsive force

Table 2 Fore/hind distribution of first and last hooves to halt from the trot and to move off from the halt

	First limb to halt		Last limb to halt		First limb to move off		Last limb to move off	
Group	Forelimb	Hind limb	Forelimb	Hind limb	Forelimb	Hind limb	Forelimb	Hind limb
Novice	1*	13*	12*	2*	15*	0*	0*	15*
Medium	4	11	7	8	15*	0*	0*	15*
Advanced	11	4	6	9	15*	0*	1*	14*

Asterisks indicate pairs of fore/hind values that differ significantly on an χ^2-test ($P < 0.05$).

Table 3 Left/right distribution of first and last hooves to halt from the trot and to move off from the halt

	First limb to halt		Last limb to halt		First limb to move off		Last limb to move off	
Group	Left	Right	Left	Right	Left	Right	Left	Right
Novice	9	5	5	9	5	10	5	10
Medium	6	8	10	5	8	7	8	7
Advanced	8	7	6	9	2*	13*	12*	3*

Asterisks indicate pairs of left/right values that differ significantly on an χ^2-test ($P < 0.05$).

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Table 4 Diagonal dissociation at contact, diagonal dissociation at lift-off and duration of suspension during the first eight steps of a transition from halt to trot for novice, medium- and advanced-level dressage horses

	Diagonal dissociation at contact (s)			Diagonal dissociation at lift-off (s)			Suspension (s)		
Step	Novice	Medium	Advanced	Novice	Medium	Advanced	Novice	Medium	Advanced
TH1	-0.24^{a} (-0.25)	-0.18^{a} (0.09)	-0.18^{a} (0.09)	-0.17^{a} (0.10)	-0.16^{a} (0.11)	-0.17^{a} (0.14)	-0.55^{a} (0.16)	-0.38^{b} (0.13)	-0.28^{b} (0.12)
TH2	-0.23^{a} (-0.24)	-0.08^{b} (0.10)	-0.01^{b} (0.07)	-0.24^{a} (0.07)	-0.16^{b} (0.08)	-0.14^{b} (0.08)	-0.45^{a} (0.14)	-0.26^{b} (0.11)	-0.13^{c} (0.09)
TH3	-0.15^{a} (-0.15)	-0.04^{b} (0.06)	0.02^{c} (0.04)	-0.23^{a} (0.09)	-0.19^{a} (0.06)	-0.10^{b} (0.10)	-0.28^{a} (0.12)	-0.12^{b} (0.10)	-0.03^{c} (0.05)
TH4	-0.06^{a} (-0.07)	$-0.02^{a,b}$ (0.04)	0.03^{b} (0.03)	-0.16^{a} (0.09)	-0.09^{b} (0.09)	-0.05^{b} (0.07)	-0.17^{a} (0.13)	-0.05^{b} (0.07)	0.03^{c} (0.03)
TH5	-0.01^{a} (-0.02)	$0.01^{a,b}$ (0.03)	0.04^{b} (0.02)	-0.09^{a} (0.07)	-0.04^{b} (0.06)	0.01^{b} (0.02)	-0.09^{a} (0.12)	-0.02^{b} (0.04)	0.04^{b} (0.04)
TH6	-0.02^{a} (-0.03)	0.03^{b} (0.02)	0.05^{b} (0.03)	-0.03^{a} (0.10)	-0.01^{a} (0.04)	0.01^{a} (0.02)	-0.06^{a} (0.09)	-0.01^{a} (0.03)	0.05^{b} (0.03)
TH7	0.02^{a} (0.01)	0.02^{a} (0.02)	0.04^{b} (0.02)	0.00^{a} (0.06)	0.02^{a} (0.02)	0.01^{a} (0.02)	-0.04^{a} (0.04)	-0.01^{b} (0.03)	0.06^{c} (0.03)
TH8	0.01^{a} (0.00)	$0.03^{a,b}$ (0.03)	0.04^{b} (0.02)	0.01^{a} (0.06)	0.02^{a} (0.02)	0.01^{a} (0.03)	-0.02^{a} (0.04)	-0.02^{a} (0.03)	0.05^{b} (0.04)

Step 1 is the first step out of the halt. A negative value for suspension indicates the amount of overlap between diagonal stance phases. Within each variable, values with the same superscripts across a row do not differ significantly between levels of training ($P < 0.05$).

developed by the deep digital flexor muscle may also be reduced as speed decreases.

When trotting at steady state, the amount and type of diagonal dissociation are thought to be related to the horse's balance; positive diagonal dissociation is indicative of greater elevation of the forehand, which is associated with higher scores in all movements. Consequently, dressage horses with relatively large positive dissociations at contact receive high-judged scores for the quality of the trot[22] and higher placings in competitions[6]. Mean values for diagonal dissociation at contact and lift-off in advanced dressage horses do not differ significantly between collected, working, medium and extended trot[8]. Thus, we did not expect differences in diagonal dissociation due to the fact that the strides immediately preceding the transition were performed at working trot in the novice horses and at collected trot in the medium and advanced horses.

When quadrupeds change speed, there is a net craniocaudal acceleration that tends to cause the body to rotate around its transverse axis in a pitching motion. For example, when forward speed slows, the tendency to pitch forward onto the forehand is overcome either by strutting the limbs forward or by increasing the vertical force exerted by the forelimbs[23]. The diagonal support pattern of trot is inherently stable in that it allows increased craniocaudal forces from a fore- or hind limb to be balanced by an increased vertical force in the other limb of the diagonal pair, so that the resultant ground reaction force maintains its alignment through the centre of mass[23]. When horses make an abrupt natural transition to halt, the forelimbs are braced forward as struts, but a transition performed in this manner is not appropriate in dressage because the associated forward pitching motion puts the horse's balance onto the forehand. We hypothesize that the more highly trained dressage horses in our study were able to control their balance as speed decreased in the TH transition by increasing the vertical force in the forelimbs and thus maintain the trot rhythm with positive diagonal dissociation and suspension. By comparison, the novice horses showed an earlier change to a negative diagonal dissociation and loss of suspension that may have been a result of not having learned the technique or developed sufficient strength to generate the necessary vertical force with the forelimbs to avoid pitching onto the forehand. Further studies combining kinematic data with ground reaction force data using inverse dynamics or a modelling approach could be used as a next step in understanding the kinetics of the transitions.

At the halt, the combined mass of the mounted horse and rider is distributed among the four limbs, with each forelimb carrying approximately 30% of the combined horse-rider mass and each hind limb

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carrying about 20%, which represents a slightly greater percentage of weight on the forelimbs than in the unmounted horse (Nauwelaerts, unpublished). All horses moved off from the halt by lifting a forelimb first. This seems counterintuitive given that the forelimbs are bearing more weight than the hind limbs. In people, gait initiation involves shifting the centre of pressure towards the initial swing limb and before it moves forwards and then towards the stance limb, which is responsible for generating momentum[24]. These authors concluded that gait initiation was centrally programmed. In horses, it is probable that the centre of pressure is shifted laterally and/or caudally away from the forelimb that initiates the move off. Abourachid[25] suggested that activation of the central pattern generators by the brain stem occurs in a craniocaudal sequence, which could offer an explanation for the fact that forelimb activation precedes hind limb activation. The higher frequency of advanced horses moving off with the right forelimb may be an indication of an inherent sidedness pattern originating from the horse or the rider.

A direct transition from HT would require a diagonal pair of limbs to be lifted synchronously, while the grounded pair of limbs generates the vertical and longitudinal forces to propel the horse into trot. Steady-state trotting mechanics makes use of elastic recoil, which would not be present in moving off from the halt and it is unlikely that the muscles would generate sufficient force to initiate the move off from the halt directly into a suspension phase. Thus, it is to be expected that horses would take one or more steps without suspension and that stronger horses would require fewer steps to establish a suspension phase. The advanced horses in this study were moving their limbs in a trotting sequence by step 2 and showed a suspension following step HT3, whereas most novice horses did not establish a trotting sequence until HT4 and did not show a distinct suspension phase, though the amount of overlap decreased as they moved away from the halt. As explained earlier, the lack of suspension may have been related to the method of detecting hoof contact and lift-off.

Conclusions

It is concluded that dressage horses competing at an advanced level perform the TH and HT transitions more directly than horses competing at a novice level. The differences are apparent in terms of taking fewer non-trot steps and the ability to maintain positive diagonal dissociation and a suspension phase in the steps closer to the halt.

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