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Harnessed vs. mounted Standardbreds on the track: changes in gait and physiological variables

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Summary

Reasons for performing study: **It has become apparent through analysis of elite races over the past 20 years that mounted races are always slower than harnessed races when performed by the same horses over the same distances on the same tracks.**

Objectives: **To investigate and compare physiological and gait variables in mounted and harnessed activities in trotters.**

Methods: **Ten trotters were taken at random in 2 standardised field exercise tests one week apart: a harnessed and a mounted test with standardised weight jockeys and drivers. Speed, heart rate (HR), respiratory frequency (RF), blood lactate concentration (La), stride characteristics (length, frequency [SF], symmetry, regularity, dorsoventral displacement of the sternum and vertical, longitudinal and lateral activities measuring the amount of deceleration and acceleration along the 3 axis) were measured.**

Results: **Paired *t* tests and an analysis of variance were calculated between the 2 conditions and revealed that V_4 (speed for a La of 4 mmol/l), V_{200} (speed for a HR of 200 beats/min), stride length, trot symmetry, lateral activity were lower in the mounted condition. In contrast, RF, SF, dorsoventral displacement, vertical and longitudinal activities were significantly higher in mounted horses compared to harnessed horses.**

Conclusion: **The significant physiological and biomechanical differences between pulling whilst harnessed and being ridden reflect an increase in the energy requirement of locomotion in the mounted condition compared to the harnessed condition. Trotting mounted at maximal speed is more demanding for the horse than harnessed as reflected by the lower V_4 and V_{200} and some gait variables change in relation to this phenomenon.**

Potential relevance: **This study demonstrates that trotting mounted at sub-maximum and maximum speed is more demanding for the horse when ridden and that it modifies some gait variables, either as a result or even as a possible cause.**

Introduction

The are 2 types of trot race competitions in France: harnessed and mounted races, both on distances between 1600 and 4000 m, with about one third being performed mounted. By studying race performances, it was observed that the average maximum speed is usually about 2 sec/km slower in a mounted race than a harnessed race on the same tracks and over the same distances (V. Mottini, unpublished data).

Several studies have investigated the effects of loading compared to unloaded controls on energetics, kinematics and performances in man (Cooke *et al.* 1991; Abe *et al.* 2004; Bastien *et al.* 2005), and in animals such as insects (Kram 1996), birds (Chai *et al.* 1997) and horses (Hoyt *et al.* 2000; Wickler *et al.* 2001). Very few studies have been performed in racehorses (Thornton *et al.* 1987). Racehorses always perform maximum exercise with an external factor such as a jockey or sulky and driver. It is therefore, of a great interest to study how this factor affects energetics and locomotion. In particular, the comparison of the effects of carrying a jockey or hauling a sulky and driver has never been done.

Therefore the purpose of this study was to investigate the effect of carrying a standardised weight jockey compared to hauling a sulky and driver on biomechanical and physiological parameters during a standardised exercise test on the track.

Materials and methods

Horses

Ten French Trotters (6 mares, 4 geldings) age 3–10 years (mean ± s.d. 5.9 ± 2.4 years) were used. All horses recruited to participate in the study were previously accustomed to exercise mounted and harnessed during training. Horses were in good athletic condition and at the same training level as they were all entrusted to two schools of racing.

Jockeys and drivers

Jockeys and drivers were weighed and handicapped with lead at a standardised weight of 65 kg, i.e. approximately 14% of the horse bodyweight. Drivers used the same well balanced race-sulky and jockeys the same race-saddle.

Standardised exercise tests

Horses were involved in 2 standardised field exercise tests (SETS) as previously described by Demonceau and Auvinet (1992): after a 10 min warm-up at about 350 m/min, they performed three 3 min stages at increased speed. Randomly, one test was performed harnessed and the other mounted one week apart. The speed of each stage for mounted and harnessed horses was 500 m/min, then 570 m/min and 640 m/min. Immediately after the third stage they trotted at maximum speed for 250 m. These tests were performed

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on 2 almost identical race tracks: 5 horses performed the mounted and harnessed exercise tests on the first and 5 on the second track. The reproducibility of this standardised exercise test under field conditions was described by Dubreucq *et al.* (1995).

Physiological parameters

Velocity was recorded during tests with a tachometer (SRM)[1] on the sulky. The driver used information from the tachometer to keep the speed as constant as possible during each stage. The mounted horse performed the test behind the harnessed one, which controlled trotting speed, except during the acceleration at maximum speed. Electrodes were placed under the saddle or the harness to record heart rate (HR). Blood samples were taken from the jugular vein at the end of each stage into tubes containing fluoride and oxalate for the determination of whole blood lactate concentration (La) using the enzymatic method of Boehringer. Two physiological variables were calculated individually: V_4, the horse's velocity when its blood lactate concentration reached 4 mmol/l and V_{200}, velocity when heart rate reached 200 beats/min. Horses were fitted with a microphone between the nostrils and an analogue tape-recorder[2]. The respiratory sound analysis allowed respiratory frequency (RF) measurement.

Biomechanical parameters

The 3-dimensional accelerometric device used for the experiment was an Equimetrix 3D accelerometric transducer, connected to a small data logger[3]. The transducer consisted of 3 orthogonal accelerometers measuring accelerations at the sternum, along the dorsoventral, longitudinal, and lateral axis of the horse. Stride is defined as a full cycle of limb motion and, at a constant speed, the trot can be considered as a sum of stationary periodic motions. Gait parameters measured were:

- Stride frequency (SF): number of strides/sec, equal to the inverse of stride duration. It was measured by finding the frequency of the main peak of the power spectrum calculated by a fast Fourier transform (FFT) of the dorsoventral acceleration signal.
- Stride length (SL, m): deduced from the relationship SL = velocity/SF.
- Stride regularity (REG) : the regularity is a sum of the coefficients of correlation corresponding to the peaks of the autocorrelation function of the dorsoventral acceleration, measured at a time equal to the half stride and stride duration. It measures the acceleration pattern similarity of successive strides.
- Stride symmetry (SYM): symmetry is a coefficient of correlation, corresponding to the peak of the autocorrelation function of the dorsoventral acceleration measured at a time equal to half stride duration. It measures the acceleration pattern similarity of the right and left diagonals.
- Dorsoventral displacement (DVD, cm): dorsoventral displacement of the sternum was estimated by a double integration of the dorsoventral acceleration signal.
- Dorsoventral activity (DVA, g^2/Hz): this was the integral (cumulative sum of the energy modules 0–25 Hz) of the power spectrum obtained by FFT from the dorsoventral acceleration signal. This variable measured the activity of suspension and loading of the limbs.
- Longitudinal activity (LONG, g^2/Hz): this is the integral of the power spectrum obtained by FFT from the longitudinal acceleration signal. This variable measured the amount of deceleration and acceleration along the longitudinal axis.
- Lateral activity (LAT, g^2/Hz): this is the integral of the power spectrum obtained by FFT from the lateral acceleration signal. This variable measured the amount of deceleration and acceleration along the lateral axis.

Data analysis

The route taken by the horses on the track was recorded as proof of time, by the GPS system Garmin 12[4] placed on the left shaft of the sulky and left arm of the jockey. This system also measured the spontaneous speed every 2.5 sec. A custom-designed programme was used to synchronise the acceleration, respiratory and GPS signals. Samples of 20.048 sec, at constant speed, in a straight line were analysed. The accelerometric data analysis was realised by signal analysis procedures, developed under a scientific software environment (Matlab 5)[5], to obtain both dynamic and temporal stride variables. Finally, respiratory sound analysis was done consisting of counting the number of expiration in the same sample in order to determine RF. Locomotor and respiratory coupling was then calculated from the SF/RF ratio.

Statistical analysis

The values of V_4 and V_{200}, RF, and biomechanical parameters were calculated in both conditions: harnessed and mounted, the contrast assessed by a paired *t* test and an analysis of variance. Duncan's *post hoc* tests were calculated if differences appeared. A level of significance of $P<0.05$ was used throughout this study for the tests.

Results

Exercise test

The velocity was the same in harnessed and mounted horses for each trial enabling physiological and biomechanical variables to be compared. Table 1 shows the physiological results of the population studied.

Physiological parameters

Heart rate values were higher in the mounted against the harnessed condition during exercise at the same intensity (P = 0.04) (Tables

TABLE 1: Description of the population, mean physiological measurements (± s.d.)

	Velocity (m/min) Mean (± s.d.)		Heart rate (beats/min) Mean (± s.d)		Lactate (mmol/l) Mean (± s.d.)		RF (breaths/min) Mean (± s.d.)	
Stage	Harnessed	Mounted	Harnessed	Mounted	Harnessed	Mounted	Harnessed	Mounted
1	513 (11)	512 (5)	171 (10)	178 (8)	0.9 (0.6)	1.3 (1.2)	1.50 (0.32)	1.67 (0.31)
2	579 (8)	581 (8)	187 (6)	189 (4)	2.1 (1.1)	3.3 (1.2)	1.68 (0.28)	1.76 (0.32)
3	643 (9)	652 (14)	205 (8)	209 (8)	6.0 (2.4)	6.7 (2.9)	1.69 (0.28)	1.91 (0.23)
4	743 (22)	713 (35)	217 (5)	220 (10)	/	/	1.70 (0.27)	1.90 (0.25)
	ns		Mean change = 4 beats/min (P = 0.04)		ns		Mean change = 0.17 breaths/min P = 0.04	

1 and 2). No significant changes were found for La according to the condition. However, V_4 and V_{200} were found to be different considering the condition (Fig 1). Mounted horses showed significantly lower V_4 and V_{200} (608 ± 24 and 605 ± 36 m/min, respectively) compared to harnessed horses (622 ± 26 and 625 ± 24 m/min). The RF during exercise was found to be higher ($P = 0.04$) in mounted = 1.80 ± 0.28 breaths/sec than the harnessed condition which was 1.64 ± 0.29 breaths/sec; however, there was no effect of SET stage.

Locomotor parameters

All locomotor variables were significantly different in the 4 stages except symmetry and DVD which were constant at increasing speed (Table 2). Ate each stage of the SET, the speed was similar in both conditions. Table 2 shows the condition influence at different velocities on the locomotor variables. SL, symmetry and lateral activity were lower in the mounted (SL = 5.06 ± 0.44 m, Sym = 175 ± 61, LAT = 25.4 ± 13.3 g^2/Hz) compared to the harnessed condition (SL = 5.23 ± 0.41 m, Sym = 224 ± 52, LAT = 34.3 ± 20.7 g^2/Hz). Conversely, SF, DVD and vertical and longitudinal activities were significantly higher in mounted (SF = 2.04 ± 0.15, DVD = 7.28 ± 1.41 cm, DVA = 56.9 ± 12.4 g^2/Hz, LONG = 52.7 ± 26.9 g^2/Hz) compared to harnessed trial (SF = 1.98 ± 0.15, DVD = 6.37 ± 1.40 cm, DVA = 46.8 ± 11.7 g^2/Hz, LONG = 36.7 ± 17.7 g^2/Hz) (Fig 2). No significant change was shown for regularity of the trot when studying harnessed vs. mounted. Finally, the locomotor and respiratory coupling approached a 1/1 ratio and was not modified by the condition (Fig 3).

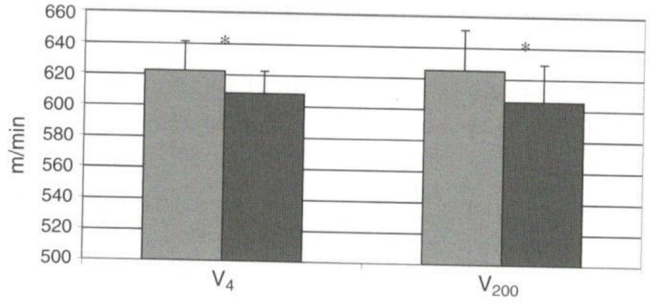

Fig 1: Physiological variables in the 2 discipline groups. = Difference between the mounted and the harnessed condition. ▨ = Harnessed; ■ = Mounted.*

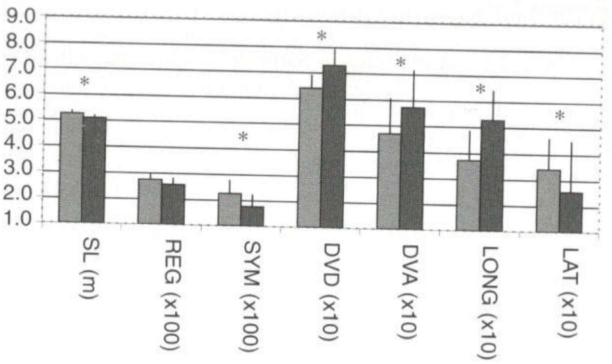

*Fig 2: Gait variables in the 2 discipline groups. * = Difference between the mounted and the harnessed condition. ▨ = Harnessed; ■ = Mounted.*

Discussion

Although a mounted effort is believed to be harder than a harnessed one at the same intensity, and race best times are always found to be lower in mounted races, no data are available to describe physiological characteristics that may be an expression of such a difference.

The present aim of the study was to understand the physiological and biomechanical parameters of mounted and harnessed sub-maximum and maximum exercise in order to explain the lower mounted race best times, about 2 sec/km slower than harnessed over the same distance.

Methodological background

The standardised field exercise test has been previously described and validated (Demonceau and Auvinet 1992; Dubreucq *et al.* 1995; Casini and Greppi 1996; Couroucé 1999). Physiological variables V_4 and V_{200} are available tools to evaluate athletic potential of standardbred racehorses and are related to performance (Leleu *et al.* 2005). Validation and reproducibility of the accelerometric measurements with Equimetrix have also been previously described in trotter racehorses (Barrey *et al.* 1995; Leleu *et al.* 2002, 2004). This method allows the calculation of some stride characteristics.

Modifications of physiological variables

V_4 and V_{200} measured in this study were respectively 622 ± 26 m/min and V_{200} = 625 ± 25 m/min in harnessed horses, and corresponded with results described by Casini and Greppi (1996) and Couroucé (1999). V_4 and V_{200} were lower in mounted than in harnessed tests. The reduction in both V_4 and V_{200} when ridden reflected the increased demand for oxygen imposed on the horse when compared to a harnessed exercise. Thornton *et al.* (1987) noticed a similarly significant decrease in V_4 and V_{200} caused by an additional load. They studied 5 Standardbred trotters performing a loaded (load of 10% bwt) and then unloaded test on a treadmill. Horses performed an incremental exercise test at speeds of 5, 6, 7 and 8 m/sec for 2 min

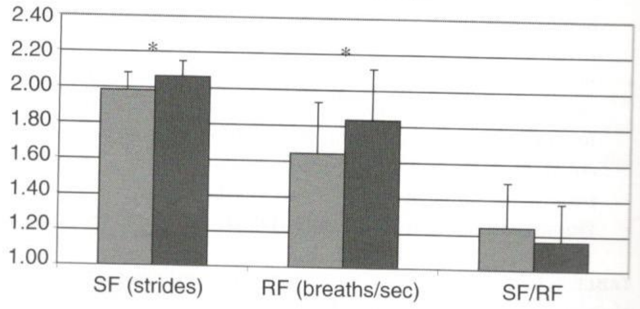

Fig 3: Stride frequency, respiratory frequency and locomotor-respiratory coupling in the 2 conditions. = Difference between the mounted and the harnessed condition. ▨ = Harnessed; ■ = Mounted.*

TABLE 2: Results of the analysis of variance testing influence of condition and stage effect

	V	RF	SF	SL	REG	SYM	DVD	DVA	LONG	LAT
Condition	ns	0.04	0.02	0.01	ns	0.002	0.02	0.001	0.001	0.01
Stage	P>0.001	ns	P>0.001	P>0.001	0.003	ns	ns	0.03	P>0.001	P>0.001

sequentially at a 6.5% slope without a load. HR, La, and respiratory rate were recorded and mean values determined. V_4 and V_{200} were also calculated. Two days later the horses repeated the initial test while carrying the load and the same observations were made. The mean change with load was 80 ± 59 m/min concerning V_4 and 29 ± 20 m/min concerning V_{200}. Differences found in our study were 14 ± 13 m/min and 20 ± 25 m/min, respectively. The important change in V_4 observed by Thornton *et al.* (1987) can be explained by a large difference in the 5 horses: 2 had an 11 and 21 m/min difference and the other 3 a 130, 113 and 125 m/min difference in V_4 when loaded.

It was hypothesised that the 3 horses struggled to carry the load, possibly as a result of the short time period between the 2 tests: 2 days is very little for time for recovery from a final La of 10 mmol/l after exercise. As regards the RF, the average values found between 1.50 and 1.91 breaths/sec corresponded with Thornton *et al.* (1987) results. Moreover, as described in our study, a significantly higher respiratory rate in the mounted condition was recorded. Thornton *et al.* (1987) describe 5 trotters performing a 5 min unloaded followed by a 5 min loaded exercise, at their loaded V_4 as the exercise speed, that respiratory rate was higher but not significantly different (0.15 breaths/sec) when loaded. Horses were only exercised at sub-maximum speed, which could be a cause for this different result. Moreover, the RF that was higher in the mounted condition, but independent of the exercise speeds, showed a different respiratory pattern in mounted compared with harnessed horses.

Modifications of linear and temporal variables

In this study, mean SF observed were higher than those described by Thornton *et al.* (1987) of 1.82 ± 0.07 stride/sec. Horses in our study were exercising in the field, whereas Thornton *et al.* (1987) studied horses on a treadmill. Therefore, the comparison of trot locomotion on the treadmill and in the field shows a SF decrease and a SL increase on the treadmill (Barrey *et al.* 1993; Buchner *et al.* 1994; Couroucé 1997). This difference between track and treadmill locomotion could explain our values.

In comparing the two conditions, some significant differences were observed in temporal variables. In the mounted condition we found a significant increase in SF (harnessed SF = 1.98 ± 0.10 stride/sec, mounted SF = 2.06 ± 0.06 stride/sec, P = 0.02) and a significant decrease in SL (harnessed SL = 5.24 ± 0.24 m, mounted SL = 5.07 ± 0.25 m, P = 0.01) in comparison with the harnessed condition. Thornton *et al.* (1987) also found similar results as they described that the additional load resulted in a significant increase in SF (mean change with load = 0.03 stride/s) and therefore a decrease in SL (mean change with load = -0.08 m). These changes were lower than ours as a result of the exercising speed, which was lower in the study of Thornton *et al.* (1987) (between 390 and 488 m/min vs. 500 m/min to maximum speed in this study), SF and SL being very velocity-driven. In man, the shorter SL and higher SF observed when carrying a backpack (40% bwt) have been described as the result of a decreased pelvic rotation, which required an increase in SF to maintain the demanded constant speed (Lafiandra *et al.* 2003).

The significantly lower SF in harnessed horses could be associated with the significantly lower RF, as well as the higher SF and RF in mounted horses. In fact, the 2 variables varied in the same way to finally reach a locomotor and respiratory ratio not modified by the condition. The change observed in the mounted horses' respiratory pattern was possibly induced by the SF modification in this condition, in order to keep a quite constant locomotor-respiratory coupling close to a 1/1 ratio as previously described in two trotters on a treadmill (Barrey 2000).

Modifications of dynamic gait variables

Symmetry quantifies the ability of the horse to produce the same pattern of acceleration with the right and left diagonals. This variable has been found to be significantly lower in mounted horses. It could probably be related to the jockey, who may create some interference at high speed. A larger range of motion in accelerometric data was found in mounted horses. Actually, significantly higher DVD, vertical and longitudinal activities were reported in the mounted condition in this study. This may, at least partly, explain the higher energy requirements in the mounted condition.

The significantly higher DVD, vertical and longitudinal activities could also be a result of the jockey possibly modifying and hampering the movements of the horse. However, the regularity, which reflects the capacity of the horse always to repeat the same stride, was not influenced by the condition and showed that the mounted condition lead the horse to an asymmetric, scattered but regular locomotion.

Lateral activity was significantly lower in the mounted trial possibly due to the girth that could have been applied with a superior tension in mounted than in harnessed horses, or to the tension of the jockey's legs around the thorax. This could have lead to a bias because of the position of the locomotion data device that recorded acceleration at the sternum, being included in the girth.

Economy of locomotion

Use of, and interest in, triaxial accelerometers to quantify the energy expenditure of physical activities has been reported in man (Bouten *et al.* 1994; Aminian *et al.* 1999). In our study, some variables could reflect a better economy of the harnessed locomotion by the ability to maintain a more symmetric locomotor pattern, limiting thoracic displacements (i.e. minimal DVD and vertical and longitudinal activities), and more advantageous SF and SL. The altered mounted locomotion biomechanics led to an increase in energy expenditure.

The effect of load on cost of transport was demonstrated by Wickler *et al.* (2001) who studied preferred speed in 7 trotting horses exercising with and without a 19% bwt saddle. They described a significantly lower preferred speed when loaded and metabolic rate increased an average of 17.6% for all speeds. This increase was lower than the decrease calculated in our study for V_4 and V_{200} (respectively, 2.1 and 3.3%). A possible explanation for this was that we compared 'carrying and hauling a load' and not 'carrying a load vs. no load'.

Conclusion

The aim of this work was to highlight the existence of physiological and gait differences between trotter racehorses involved in harnessed or mounted exercise at submaximum and maximum speed. The significant changes between harnessed and mounted condition may reflect an increase in energy cost of locomotion in mounted compared to harnessed exercise. This higher energy cost may be related to the weight loading and also to the horse-rider interaction. Moreover, as mounted condition increases the metabolic cost of exercise, trainers have to take into account this higher energy expenditure when training mounted horses.

Manufacturers' addresses

[1]Schoberer Rad Meßtechnik, Jülich, Germany.
[2]Aiwa Business Europe, Capelle aan den Ijssel, The Netherlands.

[3] Centaure Metrix, Fontainebleau, France.
[4] Garmin Corporation, Olathe, Kansas, USA.
[5] The MathWorks Inc, Natick, Massachusetts, USA.

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