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Heart rate and blood lactate responses during exercise in preparation for eventing competition

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Summary

The aim of this study was to investigate the heart rate and blood lactate responses to exercise in event horses in normal training, and to compare them to those encountered in eventing competition. It was hypothesised that the responses during exercise in the course of training for CCI* events would be significantly different from those of the Cross-Country day. Heart rates and blood lactate concentrations were measured in 13 elite event horses after intense exercise sessions conducted during the late stages of preparation for CCI*** or CCI**** 3-day-event competition. Mean ± s.d. heart rate during exercise was 138 ± 17 beats/min and mean blood lactate concentration after exercise was 1.0 ± 0.6 mmol/l. These values were compared to heart rates and blood lactate concentrations recorded during and after a CCI*** Cross Country course using unpaired *t* tests (unequal variances) and 99.9% confidence interval analysis. Mean heart rates during and blood lactate concentrations after the competition were 195 ± 8 beats/min and 10.2 ± 4.2 mmol/l. The 99.9% confidence intervals were 183–207 beats/min and 7.7–12.6 mmol/l. Heart rates and blood lactate concentrations recorded during exercise sessions were significantly lower than competition values (P<0.001) and lay outside 99.9% confidence intervals for most horses. Only one horse achieved heart rates and blood lactate concentrations during exercise sessions that were similar to those occurring in competition. The intensity of exercise during normal training sessions was much lower than during competition, suggesting that many event horses are not appropriately trained.**

Introduction

The modern 3-day-event is conducted over 3 or more days, and is run in accordance with rules set by the Federation Equestre Internationale (FEI). There are 4 classes, increasing in length, speed and technical difficulty, in which horses may compete according to their level of skill and fitness: Novice (Concours Complet International*), Intermediate (CCI**), Advanced (CCI***) and Olympic-level (CCI****).

The speed and endurance day is the most physically demanding of the 3 disciplines. It combines 4 phases: an initial Roads and Tracks (*Phase A*), a steeplechase (*Phase B*), a further Roads and Tracks (*Phase C*) and finally, after a mandatory 10 min recovery period and examination by an official veterinarian, Cross-Country (*Phase D*). In a full Olympic-level CCI**** event, the Speed and Endurance test can last up to 2 h. The distances and average speeds of each phase are typically 7700m at 220m/min (*Phase A*), 3450m with 8–10 jumps at 690 m/min (*Phase B*), 13200 m at 220 m/min (*Phase C*) and 7400 m with up to 45 jumping efforts at 570m/min (*Phase D*). The competition therefore combines long-term low-intensity exercise (Roads and Tracks) with medium-term high-intensity exercise (Steeplechase and Cross-Country).

The physiological demands of equine competition are often measured in terms of plasma or whole blood lactate concentration. Significant lactate accumulation is well documented in event horses competing in the Speed and Endurance at 1* and 2** levels (Rose *et al.* 1980a,b; Amory *et al.* 1993; Andrews *et al.* 1994; Sommardahl *et al.* 1994) and at 4**** level (Marlin *et al.* 1995). A small number of horses have been tested for lactate response at 3*** level in 2 separate studies (White *et al.* 1995a; Muñoz *et al.* 1999). The results of these studies show that *Phase D* involves substantial recruitment of anaerobic metabolism, and also suggest that the lactate response to the cross-country is independent of the star rating of competition.. However, a study by White *et al.* (1995b) on horses competing in one-day event competition found significant differences in postcross-country plasma lactate concentrations between the different levels. There have been no reports of blood lactates after exercise sessions in horses being prepared for an eventing competition .

Typical average heart rates achieved during the Speed and Endurance test are 100–120 beats/min (*Phase A*), 180–210 beats/min (*Phase B*), 110–120 beats/min (*Phase C*) and 170–200 beats/min (*Phase D*) (Amory *et al.* 1993; Marlin *et al.* 1995; White *et al.* 1995a,b; Muñoz *et al.* 1999). As with lactate concentrations, there are only small differences in observed mean heart rates among horses competing in competitions of different star ratings (Amory *et al.* 1993; Marlin *et al.* 1995; White *et al.* 1995a; Muñoz *et al.* 1999). Most reports show that heart rate increases steadily throughout the cross-country from 170–190 beats/min at the beginning of the course, to 190–210 beats/min at the end of the course (Amory *et al.* 1993; Marlin *et al.* 1995; White *et al.* 1995a).

In order to reach a level of fitness where the high demands of a CCI*** Speed and Endurance test can be met, it is essential that fitness training in preparation for competition be appropriate. As with many areas of equine performance, training methods for eventing are often empirical, based on tradition, slowly-acquired experience and the often-conflicting testimonies of experienced riders and trainers, rather than scientific evidence. As a result, there is a large range of training programmes employed, all with the ultimate goal of producing

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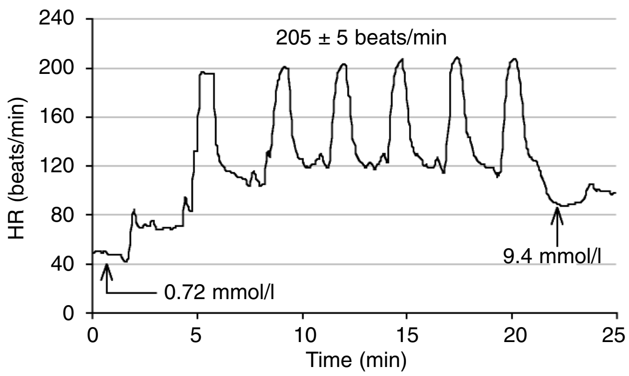

Fig 1: Heart rates over time during 6 successive hill gallops in Horse A. *Timing and values for blood lactate concentrations are also shown.*

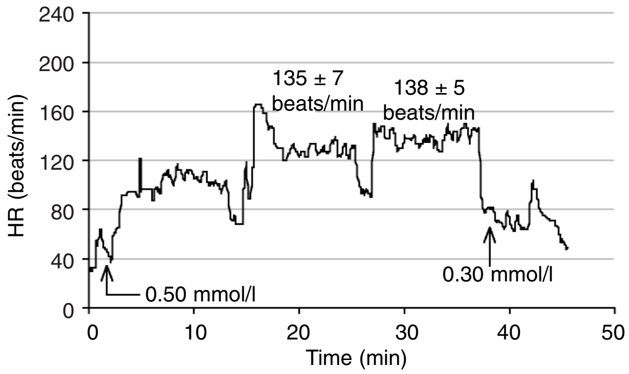

Fig 2: Heart rates over time in Horse A *during swimming exercise. Timing and values for blood lactate concentrations are also shown.*

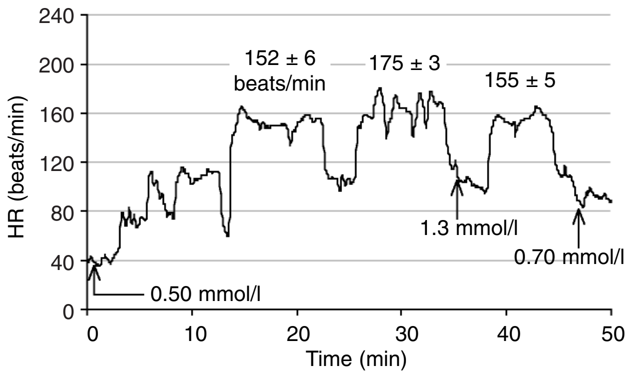

Fig 3: Heart rate over time during beach canters in Horse C. *Timing and values for blood lactate concentrations are also shown.*

an injury-free horse with optimum fitness. Many elite riders are, however, keen to adopt a more rational approach, which specifically targets the requirements of the competition for which they are training, in order to maximise performance and reduce the incidence of injury. While there is no single ideal method for training all eventing horses, following evidence-based principles of training could help prevent under- or over-training, and hence maximise performance.

There have been no previous studies of routine training methods of event horses in Australia. The aim of this study was to investigate the heart rate and metabolic responses in event horses in normal training, and to compare these responses to those encountered in competition. It was hypothesised that the responses during exercise sessions undertaken in preparation for CCI*** events would be significantly different from those in the Speed and Endurance test during competition.

TABLE 1: Breed, age, sex and rider's perceived relative fitness, where 100% equals fully fit for competition

Horse	Breed	Age (years)	Sex	Fitness (%)
A	Tb	10	G	85
B	Tb	10	G	100
C	Tb x Wb	10	G	90
D	Tb	13	G	90
E	Tb	11	G	95
F	Tb	10	G	85
G	Tb	11	G	85
H	Tb	12	F	80
I	Tb	12	G	85
J	Tb	11	G	80
K	Tb	12	G	75
L	Tb	13	G	85
M	Tb x Wb	10	G	85

Tb = Thoroughbred, Wb = Warmblood, G = gelding, F = female.

Materials and methods

Horses

Thirteen horses tested, age range 10–15 years and with varying levels of fitness and experience, were part of the New South Wales Institute of Sport Elite and Reserve Event Squads. All horses were being trained for CCI*** or CCI**** events and were ridden by their usual rider during the exercise sessions.

Exercise sessions

Exercise sessions were chosen with the intent of surveying a representative cross-section of exercise in training programs used by elite event riders. A survey of 51 training programmes utilised in preparation for competition at CCI*** level (M. G. Serrano, unpublished data) provided information on typical durations, speeds and progression of fitness training programs. On the basis of the results, the exercise sessions monitored in this study constitute a representative sample of those used to train elite event horses in Australia.

Horses performed a normal exercise session, with no change in duration, speed, or timing of the session as a result of the examination. Trainers were advised that the sessions chosen for study should be typical of an intense exercise session for the horse being prepared for competition. The physiological demands of the exercise session were determined by measurement of heart rate during exercise and blood lactate concentrations after exercise. All horses were examined about 3 weeks prior to competition in either Werribee CCI*** or Adelaide CCI***/**** events. The exercise sessions were thus at or near the maximum intensities used by riders in preparing their horses for high level event competition.

Heart rate monitoring

Heart rate was continuously recorded throughout the warm-up period and the training session using commercially available heart rate monitors (Polar Accurex II)[1]. Stored heart rate information was down-loaded onto a portable computer for analysis.

Blood samples

Two venous blood samples were taken, one before the warm-up, and one within 5 min of finishing the exercise session. Where

TABLE 2: Summary of exercise sessions and the heart rate (mean ± s.d.) and blood lactate responses to exercise. HR_{peak} refers to the mean ± s.d. heart rates recorded during the most intense intervals of the exercise session; $[La]_{rest}$ refers to the blood lactate concentration before the commencement of exercise, and $[La]_{max}$ refers to the highest blood lactate concentration measured, either during or after the exercise session

	Interval exercise session information				Physiological responses		
Horse	Activity	No.	Length (m)	Speed (m/min)	HR_{peak} (beats/min)	$[La]_{rest}$ (mmol/l)	$[La]_{max}$ (mmol/l)
A	Hill* gallops	6	425	600–650	205 ± 5	0.7	9.4
B	Track# canter	3	2700$^{\alpha}$	500–550	142 ± 12	0.5	1.4
C	Beach¶ canter	3	5000$^{\beta}$	550$^{\beta}$	175 ± 3	0.5	1.3
D	Paddock§ canter	3	4000	350–400$^{\gamma}$	127 ± 5	0.4	0.5
E	Paddock canter	3	4000	350–400$^{\gamma}$	141 ± 9	0.4	0.7
F	Paddock canter	4	4000	400	117 ± 3	0.4	0.5
G	Paddock canter	4	4000$^{\delta}$	400	132 ± 6	0.4	0.6
H	Beach canter	3	4000	450–500ε	126 ± 7	0.6	0.8
I	Beach canter	3	4000	450–500ε	151 ± 12	0.4	0.9
J	Beach canter	3	4000	450–500ε	143 ± 14	0.3	0.5
K	Beach canter	3	4000	450–500	146 ± 10	0.4	0.6
L	Beach canter	3	3200–5600$^{\phi}$	450–600$^{\phi}$	181 ± 9	0.5	2.3
M	Beach canter	3	3200–5600$^{\phi}$	450–600$^{\phi}$	174 ± 6	0.4	1.7
N	Swimming	2	500	55	138 ± 5	0.5	0.3
	Mean ± s.d.†				**138 ± 17**	**0.4 ± 0.1**	**1.0 ± 0.6**

*Hill gallops were conducted on a turf track with a slope of approximately 10%; #Sand track, 450m in diameter, slightly undulating; $^{\alpha}$Third interval 1800 m; ¶All beach canter sessions were conducted on wet sand at the water line, and minimal camber was present. $^{\beta}$Second interval incorporated 4 x 500 m sprints at 750–800 m/min. Third interval 3500 m at 520 m/min; §All paddock canter sessions were conducted on slightly undulating terrain; $^{\gamma}$Second interval included 3 x 150 m fast canters at 600 m/min; $^{\delta}$Third interval was 5000 m; $^{\varepsilon}$Speed increased to 600 m/min for the last minute of the third interval; $^{\phi}$Session consisted of three 7 min intervals; first at 600 m/min, second at 650–800 m/min, third at 450m/min; †Excludes *Horse A,* as it represents a clear outlier.

appropriate, blood samples were also taken during rest periods in the exercise session. Blood was collected by jugular venipuncture with 21 gauge needles into evacuated 5 ml tubes containing sodium fluoride and potassium oxalate (Vacutainer Systems)[2] and immediately chilled on ice. Samples were frozen at -40°C until analysed for whole blood lactate (YSI 2700 SELECT)[3].

Competitions

Heart rates were monitored in 5 horses during *Phase D* at Goondiwindi CCI*** and Werribee CCI*** events. Blood lactate concentrations were measured 2–5 min after *Phase D* in 34 horses at these 2 events.

Statistical procedures

Means ± s.d. and confidence intervals (CI) were calculated (Microsoft Excel 98)[4]. Heart rates and blood lactate concentrations in exercise sessions and competition were compared using an unpaired *t* test (unequal variances). Individual values during exercise sessions that were outside the 99.9% CI of the values during competition were deemed different (Hopkins 2002).

Results

Age, sex, breed and rider's perception of the horse's relative fitness are presented in Table 1. All riders used interval sessions utilising rest periods between bouts of exercise, and all horses performed warm-up exercise consisting of walking and trotting or cantering of between 5 and 15 min duration immediately prior to the exercise session. All training programs commenced 12–16 weeks prior to 3-day event competition. Following 4–6 weeks of graded light exercise, fast exercise was incorporated every 4 days for the remaining 8–10 weeks. All riders included between 2 and 4 one-day event competitions in preparation for 3-day event competition.

Rest periods between intervals of fast exercise consisted uniformly of 2 to 3 min walking in the sessions investigated. There was, however, substantial variation in the number, duration and speed of intervals in the exercise session among the programmes tested. The details are summarised in Table 2 together with the results for blood lactate and heart rate measurements. Also presented are the heart rate and blood lactate responses to a swimming session (N) in the same horse that completed session A .

The demands of competition were represented by the means ± s.d. of heart rates during and blood lactate concentrations after *Phases D* at Goondiwindi CCI*** and Werribee CCI*** events. They are referred to as HR_D = 195 ± 8 beats/min (n = 5) and La_D = 10.2 ± 4.2 mmol/l (n = 34). The 99.9% confidence intervals for HR_D and La_D were 183–207 beats/min and 7.7–12.6 mmol/l, respectively.

Heart rate and blood lactate concentrations were significantly lower during exercise sessions than in competition ($P<0.001$). All heart rates and blood lactate results during exercise sessions, except those from Exercise A, were also outside the 99.9% confidence intervals for HR_D and La_D.

For *Horses B–M*, mean ± s.d. heart rates achieved during training (HR_T) were 138 ± 18 beats/min and mean ± s.d. postexercise lactate concentration (La_T) was 1.0 ± 0.57 mmol/l. These differed significantly from HR_D = 195 ± 8 beats/min ($P<0.001$) and La_D = 10.2 ± 4.2 mmol/l ($P<0.001$), respectively. These results exclude Exercise A (Hill Gallops), since it was a clear outlier, and Exercise N (Swimming), since it was not representative of normal fitness exercise.

The exercise session for *Horse A* was the most strenuous observed in this study (Table 2) Exercise session A was also the only session in which the horse showed heart rate and blood lactate responses similar to those observed during competition in the cross–country phase a CCI*** event. This horse competed at the Melbourne CCI*** event. It was one of only 3 horses out of the 42 horses monitored at that event to complete the cross-country within optimum time (no time faults), and had lower (outside the 99.9% CI) post-*Phase D* blood lactate concentration (4.7mmol/l) than La_D. The horse went on to showjump a clear round and rank in the overall placings. Of the other horses monitored during training exercise sessions that could be evaluated in competition, all those that completed cross-country did so outside optimum time, with post-*Phase D* blood lactate concentrations either not different from (within the 95% CI) or above (outside the 95% CI) La_D. One horse had a post-*Phase D* blood lactate concentration of 18.0 mmol/l which was higher than the 99.9% CI. This horse was also withdrawn from competition prior to the veterinary inspection on Day 3.

Discussion

The heart rates and blood lactate concentrations after competition were similar to those reported in cross-country events by Muñoz *et al.* (1999) and White *et al.* (1995a,b). These results confirm that the event results in near-maximal heart rates and significant accumulation of lactate in the blood. The results also showed that the heart rates and blood lactate concentrations in horses during exercise conducted as part of preparation for CCI*** and CCI**** events were significantly different from those of the Speed and Endurance test. In most horses, heart rates and blood lactates were lower than those measured during cross-country competition.

The significantly lower heart rates and blood lactate concentrations in the exercise sessions compared with those in competition suggest that most horses were under-training in the sessions investigated. Under-training can compromise fitness because the responses to exercise during training depends on the intensity of exercise. Muscle buffering capacity, a factor that could influence performance in the cross-country phase, was higher in horses trained at higher relative intensities (Sinha *et al.* 1991).

Why are most eventing horses under-trained? The rationale behind current attitudes to event-training methods in Australia, as suggested by responses of those riders surveyed (M. G. Serrano, unpublished data), is related to perceptions of an increased risk of injury, and secondarily to changes in temperament and poor dressage performance, that may be associated with more intense training. The importance of time-efficiency and other specific practical limitations (eg. available terrain and facilities) also influence the design of training programs. However, in most cases, these factors did not preclude the integration of exercise with higher physiological demands in the horses studied. It is possible that improved understanding of the principles of training relating to specificity, overloading and recovery may result in wider use of more appropriately structured training programmes, which specifically target the physiological demands of cross-country competition.

Current training methods may be counter-productive. The sudden requirements for fast exercise in competition are probably more likely to cause injury in horses that are not suitably adapted to the demands of high speed exercise. This risk is multiplied in Australia, where speed and endurance courses are often held on hard ground. An obstacle to performing fast work routinely, for many riders, is a lack of suitable surfaces on which to train. Some riders have access to sand beaches, which, if there is minimal camber at the water-line, provide an ideal surface for fast work. Hills also provide a good opportunity to increase work-load without excess stress on legs, but not all riders have access to suitable terrain. Treadmill training could also be used to train horses at suitable metabolic rates without having to carry the rider. The results of the current study suggest that trainers should use measurements of heart rate during exercise or blood lactate concentrations after exercise to refine their training velocities and avoid under-training.

Trainers of event horses may also be influenced by trainers' attitudes to the effect of fitness on a horse's temperament. It seems that some riders are reluctant to jeopardise performance in the dressage phase of competition by having their horses "feeling too well". In some horses a change in temperament might be inevitable with an increased level of fitness. However this is probably a poor justification for having horses under-prepared for speed and endurance. The undertraining probably compromises performance on cross-country day, and possibly increases the risk of noncompletion, inability to recover adequately for showjumping, or injury. More studies on the interactions between exercise training, fitness and behaviour during dressage are warranted.

Interpretation of the comparisons of heart rates and blood lactates in exercise sessions and results in competition is limited because not all horses monitored during training exercise could be evaluated in competition. As well, the number of horses studied was low. Nevertheless, the results suggest that with the appropriate training methods, event horses can perform to potential on Speed and Endurance, and recover quickly enough to perform well in Showjumping.

The results of this study support the hypothesis that event horses are under-trained. Measurement of heart rates and blood lactate concentrations during and after exercise proved to be simple methods for measuring exercise intensity. Increased use of these techniques could enable refinement of training of event horses, so that the intensities of training and competition are better matched. These techniques could also be used to further study the relationships between the intensity of exercise sessions during training and performance in eventing competitions.

Acknowledgement

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Manufacturers' addresses

[1]Baumann and Haldi, Switzerland.
[2]Becton Dickinson, New Jersey, USA.
[3]Yellow Springs Instruments, Ohio, USA.
[4]Microsoft Corporation, USA.

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