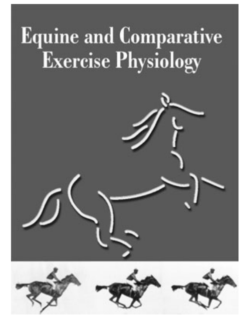
 DOI: 10.1017/S1478061507727408



Describing workload and scientific information on conditioning horses

CW Rogers [1,*], JLL Rivero [2], E van Breda [3], A Lindner [4] and MM Sloet van Oldruitenborgh-Oosterbaan [5]

[1]Massey Equine, Institute of Veterinary, Animal and Biomedical Sciences, Massey University, Palmerston North, New Zealand
[2]Muscular Biopathology Laboratory, Department of Comparative Anatomy and Pathological Anatomy, Faculty of Veterinary Sciences, University of Cordoba, Cordoba, Spain
[3]Department of Movement Sciences, Maastricht University, Nutrition and Toxicology Research Institute, Maastricht, The Netherlands
[4]Arbeitsgruppe Pferd, Heinrich-Roettgen-Street 20, D-52428 Juelich, Germany
[5]Department of Equine Sciences, Faculty of Veterinary Medicine, Yalelaan 140, 3584 CM Utrecht, The Netherlands
* Corresponding author: c.w.rogers@massey.ac.nz

Submitted 23 November 2006: Accepted 14 March 2007 **Review Article**

Abstract

At the International Conference on Equine Exercise Physiology (ICEEP7), about 70 people attended the workshop on workload and conditioning guided by the authors. Most of the audience were involved in Thoroughbred or Standardbred racing, and only a limited number of people were mainly involved in FEI equestrian disciplines (sport horses). The workshop and this review article address the measurement of workload and conditioning of the Thoroughbred racehorse. It was proposed that workload could be quantified using a few selected parameters commonly recorded in the racing industries, such as velocity and distance, to generate a cumulative workload index. The review of conditioning focuses on the Thoroughbred racehorse and examines what can be modified with training, how training programmes should be designed based upon scientific methods and how training programmes should be routinely designed in current practice. It would appear that, in general, the methods used in practice for training Thoroughbred racehorses are quite similar to those used in a set of recent scientific studies, particularly in young (2–3-years-old) Thoroughbreds. Nevertheless, both the length of the training programme and the total amount of exercise are usually shorter/lower than ideal in order to maximize physiological adaptations within the animal's body. In planning the training programme, it is very important to recognize that different adaptations occur at different rates, and this will affect the relative amount of training that should be applied to achieve specific adaptations.

Keywords: horse; training; workload; Thoroughbred; racing

Introduction

At the International Conference on Equine Exercise Physiology (ICEEP7), about 70 people attended the workshop on workload and conditioning guided by the authors. Most of the audience were involved in studying Thoroughbred or Standardbred racing, and only a limited number of people were mainly involved in FEI equestrian disciplines (sport horses).

Workload for training horses

The variables used by the workshop participants to measure workload were:

- heart rate was used by ± 50% of the audience;
- run distance by ± 50%;
- blood variables by ± 50%;
- blood gas analysis by ± 10% and
- muscle biopsies by ± 5%.

To compare the training and workload of different studies, it is essential that authors extensively describe what they have done before and during their studies.

Currently, when training programmes are described, they are quantified only with qualitative terms. This provides a limitation for the equine exercise physiologist or equine clinician to compare and relate workload to physiological response or the onset of clinical signs. The aim of this section of the workshop was to explore which measurements could be used to provide a numerical quantification of workload.

Why measure workload?

The nature of the horses' response to exercise and training can be positive or negative depending on the intensity, frequency and timing of the stimuli. For some tissue, such as bone, if the stimulus is provided in the appropriate form (such as a single 70 Hz stimulus), then only a very low dose is required[1]. For other tissues, such as cartilage, the nature of the response may be age and stimuli dependent[2].

The difficulty in measuring workload was compared to describing the journey from Lyon to Milan. On a political map, it would be described as a simple straight line, but examination of the geographical map clearly identifies that the trip will require traversing the Alps. The hesitation of the equestrian community in adopting a quantitative measure of workload may be due to the difficulty in identifying suitable field measurements that can be used to quantify the responses of the different organ systems.

Discussion among participants identified that the aerobic threshold could be a suitable measure to divide metabolic workload. The concept of 'TRIMPS'– or training impulses– was introduced[3]. Using the 'TRIMPS' concept, metabolic work can be divided into separate zones and a cumulative index of workload derived by multiplying the time spent in each of the aerobic/anaerobic zones. This index can then be used to compare metabolic workload between training sessions or between competitions such as the Tour de France and Vuelta a España[4].

For musculoskeletal response, it was identified that there was a need to quantify the intensity and the number of stride cycles. This has previously been attempted by combining velocity and distance into a CWI[5]. This index permits the comparison of musculoskeletal loading between horses and training programmes.

Conclusions

The conclusion is that it is extremely important that authors give sufficient information in their article about their horses, the history and the present training and workload of these horses to make it possible to compare different experiments or to use the data in new experiments.

Mandatory variables to describe training and workload are:

- what work was performed (treadmill, riding, etc.);
- speed ($m\,s^{-1}$) – way of determining this speed (stopwatch, GPS, etc.);
- duration (or distance);
- frequency (per week or fortnight, for example);
- repetitions per exercise unit and
- surface/footing (treadmill, sand, grass, etc.).

Interesting additional variables (when available) are:

- heart rate (beats min^{-1}) – what device was used;
- VO_{2max} or percentage thereof – the way it has been determined;
- O_2 consumption and way of measuring this;
- lactate concentration ($mmol\,l^{-1}$ – measured in either plasma or whole blood);
- acid–base balance of blood (pH, pCO_2, HCO_3^- concentration and base excess) and
- PCV and way of determining.

Conditioning Thoroughbreds in practice

Concept

Physical training aims at the following goals: (1) improve or maintain maximum performance, (2) delay onset of fatigue, (3) improve skills, (4) minimize the incidence of injuries and (5) maintain willingness and enthusiasm for exercise[6]. Conditioning is a more restricted term that means improvement in athletic performance by inducing changes that can be evaluated with objective and scientific methods. The main goal of any conditioning programme in equine athletes is to stimulate physiological adaptations within the animal's body to improve performance[7]. To reach this goal, episodes of exercise sessions and rest periods have to be well designed and balanced.

Based upon the very extensive and specialized literature published over the past 30 years, scientific approaches to training can be used to select appropriate training parameters and measure adaptations to training. However, scientific approaches to training are not widely used in the current practice of training horses. Possible explanations include: (1) the substantial controversy and difficult interpretation of published results, (2) failure of investigators to transfer knowledge to horse trainers, (3) insufficient scientific knowledge by key players involved in equine training and (4) conditioning programmes examined do not fit the 'real' world situation. As a result, it is unknown whether or not training methods routinely used in equine practice are useful to promote specific physiological adaptations responsible for improving performance. To resolve this dilemma, the following three questions were discussed with the audience: (1) What can be modified with training to improve performance in horses? (2) How should a training programme be designed to reach this goal based upon scientific data? (3) Are scientific training methods applied in practice, or are scientific training methods similar to those routinely used in practice? Because of the limited time available for discussion and complexity in the structure of the audience, the discussion was restricted to training methods in young (2–3-years-old) Thoroughbred racehorses.

What can be modified with training?

In this first point, participants discussed what can be modified with training in the horse due to the substantial controversy in published results. The central and peripheral training adaptations that enhance performance occur mainly at a cellular level and are controlled by DNA. A number of biochemical processes take place that enable the nucleotide sequence in the DNA to be translated into proteins for adaptation to occur. This process incorporates two key steps: transcription, copying of the gene sequence on DNA to mRNA, and translation, in which the gene sequence on the mRNA is used to produce new proteins. Available evidence indicates that cellular adaptations arise from the cumulative effects of changes in gene transcription occurring during the recovery period, in response to mechanical loading during each single exercise training session[8]. Thus, the activation of transcription occurs for several hours post-exercise, but this process is transient as all genes return to control levels by *c.* 22 h post-exercise. However, the mRNA content of genes is still elevated at this time, indicating that the transient increases in transcription from consecutive bouts result in accumulation of mRNA, which may represent the basis for adaptation. The cumulative effect of several training sessions or weeks of transient increases in transcription is likely to produce sufficient changes in mRNA to promote protein growth.

In this seminar, the major physiological systems responsible for performance (respiratory, cardiovascular and muscular systems) were discussed in relation to the levels of stimuli and type of training most appropriate for promoting adaptations. The maximum oxygen uptake (henceforth VO_{2max}) has been shown to continuously increase with training for several weeks to months[9]. This may have contributed to the view that ‘endurance-based, moderate-intensity training’ is more important in inducing adaptations in VO_{2max} than ‘high-intensity training’[10]. However, it is currently believed that high-intensity training is a better choice for changing VO_{2max}. Training can also result in an increase in myocardial muscle mass, chamber size and increased capillary density[11]. This increase (hypertrophy) results in an increased volume of blood being pumped per heart beat (stroke volume). A higher stroke volume means that for a specific blood flow rate, the heart rate can be lower, as more blood is being pumped per beat.

Peripheral adaptations to training include relevant changes in skeletal muscles and other skeletal tissues (bones, cartilages and tendons). At the muscular level, the most common adaptive response to training is an increase of the aerobic capacity via a qualitative remodelling of muscle fibres that acquire different biochemical and structural characteristics, i.e. increase in the number of mitochondria, increases in the activity of aerobic enzymes, increase in glucose and free fatty acid transport and fibre-type transformation in the direction from fast-glycolytic to fast-oxidative fibres[12]. Muscle strength and power can also be improved via a hypertrophic response of either all or specific muscle fibre types following some types of training in horses. Speed can also be improved with training by inducing an increase in the anaerobic capacity, but exercise of supra-maximal intensity (*c.* 140–165% of VO_{2max}) must be applied during the last phase of training[13–14].

The metabolic demands of most equestrian disciplines, including Thoroughbred racing, are largely aerobic in nature. Ideally, conditioning programmes in athletic horses should be aimed at the development of muscle properties that optimize equilibrium between the triple S: stamina, strength and speed. In Thoroughbred racehorses, incremental exercise of high intensity (*c.* 100–165% of VO_{2max}) over relatively short distances (1600–3600 m) performed in five sessions per week for *c.* 16 weeks induces relevant muscular adaptations compatible with improvements in stamina, strength and speed[13–14]. In trotters, an improvement in both aerobic capacity and strength can be induced with exercises of low to moderate intensity (*c.* 60–80% of VO_{2max}) and relatively short duration (6–12 min per session), five sessions per week for 16 weeks[9]. Prolonged training beyond this period with exercises of higher intensities (*c.* 100–110% of VO_{2max}) increases aerobic capacity, but does not improve muscle strength, and reduces speed, increasing the risk of overreaching and overtraining at the same time[9].

How should designed training programmes be based upon scientific methods?

It is obvious that one of the most underrated aspects of training (conditioning) is the design of the programme itself. To design a successful programme, previous knowledge about some basic principles of training, training parameters and other considerations is mandatory.

A basic principle of training is that a single exercise session leads to fatigue and mild cellular damage which, in turn, results in short-term adaptive responses (Fig. 1). When exercise is performed regularly and training stimulus is increased gradually, the adaptation that occurs during the recovery period of a single training session leads to an overall improvement in performance (Fig. 2). Thus, the basis of any training programme is to continually provide increased levels of stress to the physiological systems to improve performance. The 'overload principle' states that for continual adaptation, this level of stress needs to be continually increased. However, it is important to appreciate that there is an upper limit for these adaptations and, much more interesting, that individual horses will differ in relation to how well they can cope with this stress[15].

When training is too vigorous and/or rest periods between training sessions too short, performance is reduced due to an imbalance between training stress and recovery. The time period before exposure to the next training stimuli should be of sufficient duration to allow time for the training effect (adaptation) from the previous session to occur[16]. If the next training session is applied without sufficient time for recovery, overcompensation and adaptation, then performance decrements occur in the form of earlier onset of fatigue within each session.

Ideally, the design or structure of a training programme needs to consider the following previous aspects: (1) the nature of the event the horse is being trained for (i.e. discipline and distance or duration of the race), (2) the basal status of the horse (influenced by breed, age, level of fitness and training histories), (3) the total time period available for training and (4) the training facilities and climate.

The parameters of or variations to the training programme used to apply different levels of stress are: (1) the type of exercise (training tools or training facilities), (2) the length of the training programme, (3) the intensity, (4) the duration, (5) the frequency of exercise sessions and (6) the timing and length of recovery periods.

There is sufficient evidence that different *types* of exercise and/or training tools are of great benefits in maximizing training adaptations in athletic horses. These include interval training[17], training on sloped tracks[13], inclined treadmill training[9], swimming training[18] and weightlifting[19] as well as carriage driving[20], as two different forms of progressive resistance exercise training.

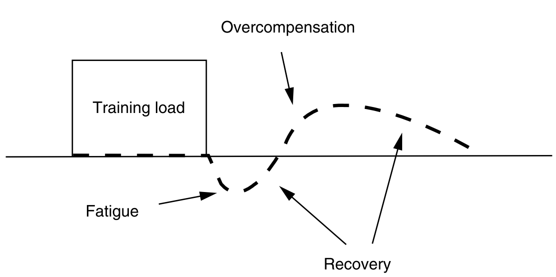


Fig. 1 Principle of training: a single session. The performance curve (dashed line) of a single training session is shown in comparison with basic performance level. During training (training load), performance is conserved but declines when the horse starts to get tired (fatigued). When the training session ends and the horse gets rest, the horse recovers from the training load resulting in a performance capacity that at first increases to the baseline level but increases further with rest (overcompensation). If the recovery period is extended further, the horse adapts again, and the performance capacity is reduced to baseline[23]

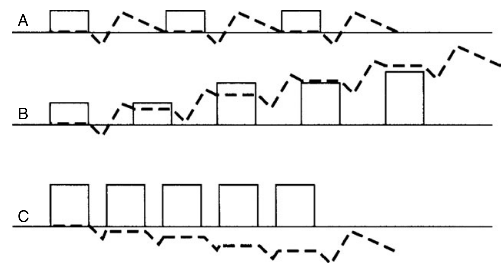


Fig. 2 Principle of training: training strategies. The performance curve (dashed line) during different training strategies. (A) Regular training sessions with the same load and relatively long rest periods do not increase performance. (B) Regular training sessions with increasing training loads with sufficient rest periods increase the performance (the overload principle). (C) Regular training sessions with increasing training loads without sufficient rest periods decrease the performance[23]

The *length* of the training programme is an important training parameter. The length of the training programme depends on the athletic demands to be placed on the horse in competition and the horse in prior level of conditioning. Despite some training adaptations occurring in horses immediately afterwards, the most relevant (in both nature and magnitude) adaptations occur within the first 10–15 weeks[7]. Based on the overload principle, the programme needs to incorporate different levels of stress (low, moderate and high).

Intensity refers to the levels of stress or speed of the exercise. This parameter needs to be closely monitored in order to avoid injuries. As a general rule, the higher the exercise intensity, the longer the recovery period to allow repair of muscle tissue damage. In the initial phase of training, the minimal exercise intensity every second day should be *c.* 50–60% of VO_{2max} to improve aerobic capacity, but higher intensities are necessary to improve strength (*c.* 80% of VO_{2max}) and anaerobic capacity (up to 165% of VO_{2max})[14].

Duration refers to the total working time during the training session or the period of time the stress (intensity) is applied. For a constant speed (intensity), duration is a principal contributor for increasing the aerobic capacity (stamina). In general, duration of the exercise should be increased gradually by *c.* 10% per week over the first 10 weeks[7]. Exercises of long duration at low intensities are more effective in inducing an improvement of aerobic capacity than short exercises of high intensities[21].

Finally, frequency of the application of the stress is the number of training sessions. During high-intensity exercises, the muscle metabolism is up to 100 times that at rest; the increased oxygen consumption results in free radical formation that causes muscle damage. It has been shown that this damage can last for 48–96 h[22]. The application of a further hard exercise session in this time period is most likely to induce further damage and delay recovery. Thus, recovery time should be: (1) long enough to allow repair and remodelling of muscle cells, but (2) not so long that reverting to the previous muscular cellular state could begin. Although there are no specific studies regarding this, most of the training studies include daily sessions for 5 days per week.

How are training programmes routinely designed in the current practice?

The current practice of the following aspects was discussed with the audience: (1) the use of different training tools, (2) the length and structure of the training programme, (3) how to monitor and apply the exercise intensity, (4) duration and (5) frequency of exercise sessions.

The first (and frequently the unique) training modality of racehorse is performing exercises (gallops) on the flat track. The use of other training tools (uphill, swimming pool, high-speed treadmill, weightlifting, straightway on the beach, small weights on the legs, hypobaric and also oxygenated boxes, etc. were discussed) depends entirely on their availability, but remains of minor importance.

In young (2–3-years-old) Thoroughbreds, the *length* of training is usually structured with an initial phase of preparation (foundation) of 4–8 weeks followed by 2–6 weeks of speed period and then by the competition period itself. The total length of the training programme prior to competition ranges usually from 6 to 15 weeks. In normal performance horses older than 3 years, this period is considerably shorter (often only 4–6 weeks).

Possibilities for monitoring exercise intensity in practice include: (1) telling the jockey to run the horse at certain paces, (2) comparing horses with other horses that have a known performance level, (3) timing the horse with a stopwatch, (4) on-board recording of heart rate, (5) measuring blood (lactate) levels after defined exercises and (6) running horses at speeds that have been shown to induce defined blood lactate concentrations in a standardized exercise test. The use of the GPS technology to monitor speed and distance is being introduced at a fast pace and may in the near future replace the stopwatch as the common tool for measuring training effort. In practice, exercise intensity on fast days varies from 16 to 18 $m\,s^{-1}$; equivalent to racing speeds for distances between 1200 and 2000 m[7].

The total duration of the work performed during a training session varies usually from 40 to 60 min. After the warm-up at walk and trot over the first 20–30 min, the horses are galloped at different rates or pace definitions for not more than 4 min on average, followed by 10–20 min of cool-down at the end of the session. In general, 2-year-old Thoroughbreds run for less time than 3-year-old and older horses. In practice, changes in the duration of gallops throughout the conditioning programme are minor if any.

Finally, with respect to the frequency of training, the usual answer of trainers as well as that written in empiric books is six sessions per week, of which two are bouts of fast work. But in reality, the number of training sessions varies from 3 to 5 days per week, of which 1 or 2 are fast work; the remaining workouts are for tapering only. Very seldom is a unique fast gallop carried out every 10 or more days.

Concluding remarks

From the discussion established, it can be concluded that, in general, the methods used in practice for training Thoroughbred racehorses are quite similar to those used in a set of recent scientific studies, particularly in young (2–3-years-old) Thoroughbreds. Nevertheless, both the length of the training programme and the total amount of exercise are usually shorter/lower than ideal for maximization of physiological adaptations within the animal's body. For example, the anaerobic phase of training (necessary to improve the speed) is usually replaced by the effect of the competition phase (racing) itself. In practical terms, the ideal is to do the least training possible that achieves the maximum benefits. In planning the training programme, it is very important to recognize that different adaptations respond at different rates, and this will obviously affect the relative amount of training that should be applied to achieve specific adaptations.

References

1 Goodship AE, Cunningham JL, Oganov V, Darling J, Miles AW, Owen GW and Kuipers (1999). A bone loss during long term space flight is prevented by the application of a short term impulsive mechanical stimulus. *Acta Astronautica* **43**: 65.

2 Dykgraaf S, Firth EC, Rogers CW and Kawcak CE (2004). Effect of exercise on cartilage and subchondral bone of young Thoroughbred horses. *AAEP Focus on Joints*. Louisville Kentucky, pp. 220–225.

3 Foster C, Florhaug JA, Franklin J, Gottschall L, Hrovatin LA, Parker S, Doleshal P and Dodge C (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research* **15**: 109–115.

4 Padilla S, Mujika I, Orbananos J, Santisteban J, Angulo F and Goiriena JJ (2001). Exercise intensity and load during mass-start stage races in professional road cycling. *Medicine and Science in Sports and Exercise* **33**: 796–802.

5 Rogers CW and Firth EC (2004). Musculoskeletal responses of 2-year-old Thoroughbred horses to early training. 2. Measurement error and effect of training stage on the

relationship between objective and subjective criteria of training workload. *New Zealand Veterinary Journal* **52**: 272–279.

6 Marlin D and Nankervis K (2002). *Equine Exercise Physiology.* UK: Blackwell Science Ltd, pp. 1–6.

7 Davie AJ (2006). A scientific approach to training Thoroughbreds. In: Lindner A (ed.), *Management of Lameness Causes in Sport Horses* (pp. 69–83). Wageningen the Netherlands: The Wageningen Press.

8 Pilegaard H, Ordway GA, Saltin B and Neufer D (2000). Transcriptional regulation of geane expression in human skeletal muscle during recovery from exercise. *American Journal of Physiology – Endocrinolygy and Metabolism* **279**: E806–E814.

9 Tyler CM, Golland LC, Evand DL, Hodgson DR and Rose RJ (1998). Skeletal muscle adaptations to prolonged training, overtraining and detraining in horses. *Pflügers Archives – European Journal of Physiology* **436**: 391–397.

10 Evans DL, Rainger JE, Hodgson DR, Eaton MD and Rose RJ (1995). The effects of intensity and duration of training on blood lactate concentration during and after exercise. *Equine Veterinary Journal Supplement* **18**: 422–425.

11 Young LE, Marlin DJ, Deaton C, Brown-Feltner H, Roberts CA and Wood JLN (2002). Hear size estimated by echocardiography correlates with maximal oxygen uptake. *Equine Veterinary Journal Supplement* **34**: 467–471.

12 Rivero JLL and Piercey RJ (2004). Muscle physiology: responses to exercise and training. In: Hinchliff K (ed.), *Equine Sports Medicine and Surgery.* London: Saunders Elsevier Ltd, pp. 45–76.

13 Miyata H, Sugiura T, Kai M, Hiraga A and Tokuriki M (1999). Muscle adaptation of Thoroughbred racehorses trained on a flat or sloped track. *American Journal of Veterinary Research* **60**: 1536–1539.

14 Yamano S, Eto D, Sugioura T, Kai M, Hiraga A, Tokuriki M and Miyata H (2002). Effect of growth and training on muscle adaptation in Thoroughbred horses. *American Journal of Veterinary Research* **63**: 1408–1412.

15 Smith RK, Birch H, Patterson-Kane J, Firth EC, Williams L, van Cherdchutham WWR and Goodship AE (1999). Should equine athletes commence training during skeletal development? Changes in tendon matrix associated with development, againg, function and exercise. *Equine Veterinary Journal Supplement* **30**: 201–209.

16 Rushall B and Pike F (1990). *Training for Sport and Fitness*. Melbourne: The Macmillan Company of Australia, pp. 1–6.

17 Lindholm A and Piehl K (1974). Fibre composition, enzyme activity and concentrations of metabolites and electrolytes in muscles of Standardbred horses. *Acta Veterinary Scandinavica* **15**: 280–309.

18 Misumi K, Sakamoto H and Shimizu R (1995). Changes in skeletal muscle composition in responses to swimming training for young horses. *Journal of Veterinary Medicine Series A* **57**: 959–961.

19 Henck RW, McKeever KH, Always SE, Auge WK, Whitehead R, Bertone AL and Lombardo JA (1996). Resitance training-induced increases in muscle mass and performance in ponies. *Medicine Science in Sports and Exercise* **28**: 877–884.

20 Serrano AL and Rivero JLLL (2000). Myosin heavy chain profile of equine gluteus medius muscle following draught-exercise training and detraining. *Journal of Muscle Research and Cell Motility* **21**: 235–245.

21 Gansen S, Lindner A, Marx S, Mosen H and Sallman HP (1999). Effects of conditioning horses with lactate-guided exercise on muscle glycogen content. *Equine Veterinary Journal Supplement* **30**: 329–331.

22 Duarte JA, Appell HJ, Carvalho F, Bastos ML and Soares JM (1993). Endothelium-derived oxidative stress may contribute to exercise-induced muscle damage. *International Journal of Sports Medicine* **14**: 440–443.

23 van Ginneken MME (2006). Adaptation of signal transduction and muscle proteome in trained horses. PhD Thesis, The Netherlands: University of Utrecht.