Training the Sportshorse

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Training and performance testing

- The horse as an athlete
- Maximum aerobic capacity
- Muscle fiber type
- Genetics
- Physiology of training
- Overtraining
- Performance testing
The horse as an athlete

<table>
<thead>
<tr>
<th>Species</th>
<th>Bodyweight (kg)</th>
<th>Speed(^a) (km/h)</th>
<th>Duration of exercise</th>
<th>(\dot{V}O_2) max (mL O(_2)/kg/min)</th>
<th>Heart rate(^a) (bpm)</th>
<th>Energy expenditure per day (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoroughbred race horse</td>
<td>450</td>
<td>64 (max)</td>
<td>2 min</td>
<td>180–200</td>
<td>240 (max)</td>
<td>30 000</td>
</tr>
<tr>
<td>Endurance race horse</td>
<td>400</td>
<td>15–35</td>
<td>6–8 h</td>
<td>180</td>
<td></td>
<td>38 000(^b)</td>
</tr>
<tr>
<td>Steer</td>
<td>470</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Goat</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Greyhound</td>
<td>34</td>
<td>64 (max)</td>
<td>60 s</td>
<td>Not reported</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>Sled dog</td>
<td>25</td>
<td>20</td>
<td>10 days</td>
<td>170</td>
<td>300</td>
<td>11 000</td>
</tr>
<tr>
<td>Human (Olympic class sprinter)</td>
<td>70</td>
<td>36 (max)</td>
<td>9.4 s</td>
<td>85</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>Human (Olympic class endurance)</td>
<td>70</td>
<td>19</td>
<td>2 h</td>
<td>70</td>
<td>180</td>
<td>2300(^c), 7000(^d)</td>
</tr>
<tr>
<td>Pronghorn antelope</td>
<td>32</td>
<td>65</td>
<td>10 min</td>
<td>300</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)During customary athletic activity.
\(^b\)Day of racing.
\(^c\)During marathon race.
\(^d\)Tour de France cyclists.
max = maximum value.

From: Equine Exercise Physiology, Hinchcliff et al. 2008
The horse as an athlete

Human
- 90mmol/kg muscle starch
- 100m sprint = 99% anaerobic

Horse
- 140mmol/kg muscle starch
- Quarter: 60% anaerobic
- Thoroughbred 30%
- Endurance 10%
- spleen contraction 50%
- RBC’s
- pump capacity hart
The horse as an athlete

- Speed to escape from predators
- Stamina to cover long distances in search of food and water
- Later on used by humans in selective breeding
The horse as an athlete

Selective breeding
The horse as an athlete

Selective breeding
- Speed: Thoroughbred 64 km/h, 800-5000m
  Standardbred 55km/h, - 3600m
  Quarterhorse  88km/h, 400m
- Stamina: Arabian 160km/day
- Strength: Belgian Draught Horse 1000kg
- Performances many other animals of comparable size cannot

Training
- may improve individuals performances, however it is impossible to turn a draught horse into a Thoroughbred..

What are the capacities of each race and of each individual?
Training and performance testing

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Maximum aerobic capacity

“the oxygen chain”

I. upper and lower airways
II. heart
III. muscle
Maximum aerobic capacity

- Aërobic: Greek for aer (air) and bios (life)
- means: oxygen dependent
- maximum aerobic capacity = the maximum capacity to extract oxygen from the atmosphere and transport it to the muscle cells
- e.g. the MAC of a horse = 2.6 that of a cow

- due to the enormous lung volume:
  tidal volume of 12l/min and up to 1600l/min during labour (Thoroughbred)

- due to the heart volume, the amount of RBC’s and the capability of muscles to extract O₂ from the blood
Maximum aerobic capacity

- due to an enormous cardiac pump capacity: 400l/min (Thoroughbred)
- due to a 50% increase in O2 transport capacity during maximal exercise due to spleen contraction
- due to huge muscle capillarity and a high concentration of mitochondria (2x cow)
Maximum aerobic capacity

- muscle mitochondria
Maximum aerobic capacity

- muscle mitochondria
  - anaerobic energy
    - ATP (seconds)
    - glucose $\rightarrow$ lactic acid (sec – min)
  - aerobic energy
    - oxidation of carbohydrates (min)
    - oxidation of fatty acids (min – hrs)
Maximum aerobic capacity

β-oxidation of fatty acids

TCA cycle
Maximum aerobic capacity

- muscle mitochondria
  - anaerobic energy
    - ATP (seconds)
    - Glucose
      lactic acid (sec – min)
  - aerobic energy
    - oxidation of carbohydrates (min)
    - oxidation of fatty acids (min – hrs)
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Muscle Fibre Type

• The muscle Fiber Type passport of your horse
• muscle = patchwork of different types of muscle fibres
• every race and every individual has its own patchwork
• 3 categories:
  – Type I (slow fibre type):
    • posture and stamina
    • aerobic oxidation
    • fatty acids as fuel
    • large storage capacity for fat
    • marathon runners train to develop this type of fibre
Muscle Fibre Type

- Type IIX (fast fibre type):
  - sprint, short lasting stamina, explosive power
  - starts with aerobic oxidation, switch to anaerobic oxidation with production of lactic acid
  - carbohydrates as fuel
  - weight lifters and sprinters train to develop this type of fibre
  - horses have a relative larger amount of this fibre type compared to humans

- Type IIA (transitional fibre type):
  - with regards to function en oxidative capacity in between type I en IIX fibres
  - may change into either type I or type IIX fibres depending on the type of training
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Genetics
Genetics

Improving performance

Thoroughbred race times have not improved since 1970. Is there no further genetic potential to increase speed?

In Standardbreds: consistent reduction in race times has been well documented for Swedish and Italian trotters; reduction is exponential and appears to approach an asymptote.
Observed trend in racing time (ki=sec/km) in Swedish Standardbred trotters (males)
Genetics

Predicted trend in the best average racing time records in the population of Swedish Standardbred male trotters
Genetics

Not just speed and earnings...

e.g. does the horse need additional tools to trot? 
is it a quick student?

coordination

what are its acceleration capacities?

acceleration

is it a fighter? does it want to finish?

bravery
The influence of genetic factors on equine muscle fiber types is clearly illustrated by dramatic variations observed between different breeds (Fig. 2.1.29)\textsuperscript{90,115,116} and between separate bloodlines within the same breed.\textsuperscript{117} Furthermore, there is a tendency for fiber type ratios (type I : type II) to be inherited.\textsuperscript{107,118} During growth and maturation, muscle fibers change in their size and histochemical properties; there is a gradual conversion of fast to slow phenotype that is especially pronounced in the first year postpartum.\textsuperscript{119} but that may continue until about 6 years of age.\textsuperscript{120-122} or older.\textsuperscript{123} Hybrid fibers play an important role in this process.\textsuperscript{124} Interestingly, aged (20+ years) sedentary horses exhibit a shift in MyHC and metabolic profiles toward faster and more glycolytic phenotypes,\textsuperscript{125,126} which may explain some of the lower exercise capacity seen in the older horse.\textsuperscript{127}

**Non-myogenic factors**

In addition to the underlying myogenic lineage, additional factors influence muscle fiber phenotype. Muscle fibers are syncytial (multinucleated), with their myonuclei arranged peripherally throughout the length of
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The physiology of training

Will to win

- Feed
- Environment
- Training

- Lungs
- Guts
- Heart
- Muscle
- Legs
The physiology of training

Aerobic exercise

• glycogenolysis in muscle and liver → glucose
• adrenaline → release of Free Fatty Acid’s

• prolonged submaximal exercise: FFA’s are the predominant fuel

although

up to 25% may remain glucose dependant
The physiology of training

Fatigue

~ intramuscular glycogen depletion

• FFA oxidation cannot produce ATP without a source of pyruvate

• glycogen depletion first in type I fibres, then IIA, finally in IIX

• replenishment may take up to 72hrs

• also ~ deamination of AMP, hyperthermia, dehydration, electrolyte depletion and lack of motivation

• Reactive Oxygen Species (ROS)

  lipid, protein, DNA damage
The physiology of training

**Anaerobic exercise**

- high intensity exercise
- glycogen and blood glucose predominant fuel
- pyruvate → lactate → acetyl-CoA
- lactate accumulation and pH decline

- removed from the cell by active transport into the blood
- lactate > 4mmol/l → saturation of the mechanism
- fatigue due to acidosis impairing both structure and function of the muscle cell
- pH buffering systems species and race dependant
Physiology of training

**Muscular response to exercise**

- neuronal (acetylcholine e.o. signaling molecules)
- and metabolic stimuli (Ca, H, altered redox state, hypoxia)
- cause altered gene regulation
  - protein synthesis (sarcomeres and cytosolic, TCA cycle enzymes, electron transport and fat oxidation enzymes)
  - increase in capillary blood flow (endothelial stress promotes angiogenesis)
**Physiology of training**

*Muscle fibre size*
stimulus: bursts of high-resistance muscle activity
e.g. jump training, weight bearing: increased type II
cross sectional area

*Muscle fibre transition*   
glycolytic oxidative
endurance training: IIX $\rightarrow$ IIA $\rightarrow$ I fibres
sprint training: IIX $\rightarrow$ IIA
strength training: IIX $\rightarrow$ IIA $\uparrow$
Physiology of training

Metabolic changes and increased capillary density

• increase in aerobic metabolism enzyme activity (Krebs/TCA cycle and fat oxidation)

• increased mitochondrial and capillary densities

• improved oxygen diffusion and removal of waste products
Physiology of training

Physiological adaptations and buffering capacity

• membrane properties of equine skeletal muscle short term moderate intensity increase Na/K pumps increased SR Ca uptake

• buffering creatine phosphate conc and carnosine

• induced cell death of unconditioned muscle cells

• faster replacement of damaged fibre by increased satellite cell activation, fibre type transition and hypertrophy
Physiology of training

Consequences of training

• increased muscle mass
• greater peak force capacity ~ cross sectional diameter
• reduction of stance time and stride duration
• force ↑ showjumpers
• acceleration and stride length race horses ↑
Physiology of training

Time lapse of training

- increase in aerobic metabolic adaptation with an increase in muscle glycogen already after 10 days of training
- structural fibre type changes may take to up to 8 months
- the upper limit after which no adaptations occur ...
- therefore most relevant training adaptations occur in the first 4 months, prolonged training may improve aerobic capacity but reduces anaerobic capacity and has no effect on strength .....
Physiology of training

Amplitude of the training response

- the response to training depends on:
- basal status of the muscle (breed, age, sex, fitness)
- stimulus applied: type, intensity, duration, frequency and volume
- little is known about relative influence of most of the factors...
Physiology of training

Intensity of exercise

• low intensity (50% of V4) for long duration (45’) after 6 weeks better for improving aerobic capacity than high intensity exercise (100% of V4) of moderate duration

• moderate to high intensity (80-100% of VO2max) of short duration (5-10’) improves both stamina and strength after 12-16 weeks of training

• whereas anaerobic capacity can only be increased in short to mid-term (up to 16 weeks) by supramaximal intensity 100-150% of VO2max or V4) of short (2’) to moderate (15’
Physiology of training

• adaptation occurs more readily in younger (< 2 years) than in mature race horses

• improved stamina through enhanced aerobic capacity is the most common response of equine skeletal muscle to training
The physiology of training

untrained

trained

conclusion:
• In a well trained horse the oxygen supply via the upper and lower airways is the limiting factor for speed
Decreased performance

1 orthopaedics
2 the oxygen chain
   I. upper and lower airways
   II. heart
   III. muscle
3 abdominal disorders
The upper airways
The upper airways
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- **Overtraining**
- Performance testing
Overtraining

- syndrome
- high intensity and prolonged training (>4 months)
  - change of mental status
  - decreased performance (racing times)
  - type IIA fibre atrophy
  - changes in muscle and mitochondria towards a more oxidative type and function
  - reduced glycogen concentration
  - ...

Overtraining
Overtraining

The training of a Standardbred

Overtraining?


Adaptation and overtraining in horses subjected to increasing training loads.

Bruin G, Kuipers H, Keizer HA, Vander Vusse GJ.

Department of Physiology, University of Limburg, Maastricht, The Netherlands.

To evaluate markers for overtraining, seven male race horses were subjected to 272 days of training consisting of daily exercise bouts of either endurance running (heart rate 140/min) or interval training (maximal heart rate), both increasing in duration and intensity. An incremental exercise test was held every 4 wk, and from day 187 it was held every 2 wk. Muscle glycogen, muscle lactate, energy-rich phosphates, adrenal response to adrenocorticotropic hormone, plasma and red blood cell volumes, and a number of blood chemical variables were measured. The horses showed symptoms of weight loss, irritability, and an inability to complete the training after the intensity of the endurance exercise was increased. Test performance was not decreased. The adrenal response to adrenocorticotropic hormone was not changed during overtraining. The decline in muscle ATP concentration during maximal exercise was less during the period of staleness, whereas plasma volume, red blood cell volume, and blood chemical variables were unchanged. It was concluded that as long as exhaustive training is alternated by light exercise, overtraining is unlikely to occur. Furthermore, no single parameter can be used to detect early overtraining.
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Performance testing

Measuring performance

- heart rate
- lactate
- speed
Measuring performance

• $\text{VO}_2 \text{ max}$

• muscle histology
Training and performance testing

Standardbred interval training
Training and performance testing

Standardbred intervaltraining
Training and performance testing

Standardbred interval training two tests with 6 weeks in between
Training and performance testing

Standardbred interval training: two horses compared to each other
Training and performance testing

Warmblood showjumper
Training and performance testing

Warmblood showjumper two tests with 6 weeks in between
Training and performance testing

standard exercise test in an endurance horse
Training and performance testing

standardized exercise test in an endurance horse
Thank you for your attention!
Thank you for your attention!
Genetics