Growth, training response and health in Standardbred yearlings fed a forage-only diet

S. Ringmark¹, L. Roepstorff², B. Essén-Gustavsson³, T. Revold⁴, A. Lindholm⁵, U. Hedenström⁶, M. Rundgren¹, G. Ögren¹ and A. Jansson

¹Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Sweden; ²Department of Anatomy, Physiology and Biochemistry, Swedish University of Agricultural Sciences, Sweden; ³Department of Clinical Sciences, Swedish University of Agricultural Sciences, Sweden; ⁴Department of Companion Animal Clinical Sciences, Norwegian School of Veterinary Science, Norway; ⁵Helgestabodarna 163, 193 91 Sigtuna, Sweden; ⁶National Centre for Trotting Education, Wängen, Sweden

The aim of this study was to, from a holistic perspective, describe the effects of a forage-only feeding system and a conventional training program on young Standardbred horses and compare data with similar observations from the literature. Sixteen Standardbred colts fed a forage-only diet for 4 months from breaking (August to December) and with the goal to vigorously trot 5 to 7 km at a speed of 5.6 m/s (3 min/km) were studied. The horses were fed grass haylage (56 to 61% dry matter (DM), 2.80 to 3.02 Mcal DE/kg DM and 130 to 152 g CP/kg DM) ad libitum, 1 kg of a lucerne product and minerals. The amount of training and number of training sessions were documented daily, and feed intake and body development were measured once every month. Heart rate (HR) was measured during and after a standardized exercise test in October and December. In December, a postexercise venous blood sample was collected and analyzed for plasma lactate concentration. Muscle biopsies (m. gluteus medius) were taken and analyzed for glycogen and fiber composition. Health was assessed in October and November by an independent veterinarian using a standardized health scoring protocol. BW and height at withers increased from 402 to 453 kg (root mean square error (RMSE) 6) and from 148.7 to 154.1 cm (RMSE 0.7), respectively, and the body condition score was 4.9 (RMSE 0.2) at the end of the study. Muscle glycogen content was 532 mmol/kg dry weight (s.d. 56). There was a significant decrease in postexercise HR (81 v. 73 bpm, RMSE 8), and the individual amount of training was negatively correlated with HR during and after exercise. Health scores were high and similar at both assessments (8.4 and 8.4 (RMSE 1.0) out of 10; P > 0.05), and the number of lost training days per month due to health problems was <0.9, with the exception of November (5.3 days). It is concluded that yearlings in training fed high-energy forage ad libitum can reach a conventional training goal and grow at least as well as earlier observations on yearlings of other light breeds.

Keywords: yearlings, training, forage, glycogen, growth

Implications

It is an animal welfare issue that high-starch diets, which are associated with health problems, are fed to horses. The need for diets that support the natural behavior and digestive and metabolic systems of horses is therefore high, and the introduction of such diets will reduce welfare problems and health-care costs for the horse industry. Until now, there have been no long-term studies on how young horses in training may grow and develop on a forage-only diet.

Introduction

In Thoroughbred and Standardbred racehorses, health problems are common. Several studies show that the risk for problems from the digestive tract is high; that is, 40% to 90% of these horses have gastric ulcers (Murray et al., 1996; Dionne et al., 2003), and 10.9% of the Thoroughbreds may suffer from colic every year (Traub-Dargatz et al., 2001). In addition, 5% have rhabdomyolysis yearly (Isgren et al., 2010), and up to 5.7% of Standardbred horses and 25.6% of Thoroughbred horses show stereotypic behavior (Redbo et al., 1998). However, the most common problem among both Standardbred and Thoroughbred horses appears to be lameness (Vigre et al., 2002; Dyson et al., 2008). Taken together, these figures indicate that there is a need for improved management of racehorses to prevent health-related problems and promote a successful career. Surprisingly, there are very few, if any, holistic studies in which training, diet, growth and health in young racehorses have been documented and evaluated under long-term, controlled conditions. However, there are some field
studies documenting age and/or training-induced metabolic changes (Lindholm and Piehl, 1974), growth (Thompson, 1995) and health (Vigre et al., 2002; Dyson et al., 2008) separately.

The use of high-starch diets is a well-documented health risk in horses. Such diets are associated with colic (Tinker et al., 1997), rhabdomyolysis (Valberg, 1998; MacLeay et al., 2000), gastric ulcers (Luthersson et al., 2009) and stereotypic behavior (Redbo et al., 1998). Starch-rich diets have also been associated with altered cartilage development in growing horses (Glade and Belling, 1984). Despite this, young racehorses are fed high-concentrate diets (Redbo et al., 1998). However, studies show that the energy requirements in adult Standardbred horses in training can be met by using forage-only diets (Connysson et al., 2006; Jansson and Lindberg, 2012) and that muscle glycogen levels, known to have an impact on performance, can be comparable to (Essen-Gustavsson et al., 2010) or only slightly lower (13%, Jansson and Lindberg, 2012) than levels in horses fed concentrate diets.

The aim of this study was to, from a holistic perspective, describe the effects of a forage-only feeding system and a conventional training program on young Standardbred horses and compare data with similar observations from the literature.

Material and methods

Horses

Sixteen American Standardbred colts (age at the start of the study 464 ± 31 days, range 400 to 518) from four Swedish breeders and after eight different sires were used. The horses had mainly American ancestors. The horses were transported to and kept at the National Centre of Trotting Education (Wången, Sweden) in August 2010, and the study started on the 20th of August and ended on the 20th of December 2010. Two horses entered the study 8 and 12 weeks after the start of the study. The experiment was approved by the Umeå local ethics committee.

Management and training

Two months before arrival at Wången, all horses had been pastured at the breeders. The final week before the study began, they were kept together on pasture at Wången for 24 h per day. For the first 1.5 months of the study the horses were stabled individually in 9 m² boxes for ~8 h a day, 5 days a week, and spent the rest of the time together in a paddock (~20 000 m²). The following month, horses were stabled for ~16 h a day, 5 days a week, and during the last month they were stabled for ~16 h a day on all days because of wet and cold weather conditions. From the beginning of November, rugs were used when horses were outside. Sawdust was used as litter in the boxes. Training started in September with breaking. The progress in training was adjusted for each horse, but most horses were walked on long reins for 2 to 3 weeks before they were adapted to a jog cart. Within 5 weeks, all horses were trotted slowly (~3.7 m/s) for 3 km a day on an oval racetrack for 4 days a week. During weeks 7 to 9, horses were trotted 5 km 4 days a week (~3.7 m/s). For weeks 10 to 17, the horses were trained 4 days a week and speed was increased gradually up to 5.6 m/s. In these weeks, approximately one-third of the training was performed at the racetrack (5 to 7 km) and the rest was performed on a slightly hilly track (4.5 km), in addition to 2.5 km on the racetrack where the last 250 m was performed as fast as the horse was willing to trot. The type of training and distance were documented, and horses that, according to the trainer’s opinion, were unhealthy were left out of training for as long as needed. The goal for all horses was to vigorously trot 5 to 7 km at a speed of 5.6 m/s (3 min per km) in December, and it was defined together with a reference group consisting of four professional trainers with international experience.

Diet and feed intake

Horses were fed squared baled grass haylage ad libitum. In the box, haylage was provided in a crib placed in one corner of the floor to minimize wastage, and in the paddock haylage was provided from three feeding stations. New haylage was provided once a day in the box and in the paddock every 3 to 4 days. From August to October, some grass was available in the paddock. On the basis of weight, dry matter (DM) content and number of bales provided in the paddock, the consumption of haylage in the paddock was calculated as 9.7 kg DM per horse and day in September when horses spent ~65% of their time in the paddock and as 7.0 kg DM per horse and day in October when 50% of their time was spent in the paddock. Because of the high consumption of haylage in the paddock, the fresh grass intake was considered to have little contribution to the total energy and nutrient intake. Water was offered from two 201 buckets in the box that were refilled twice a day and from a big tub in the paddock. The haylage used in the experiment (Table 1) was harvested in Enköping, Sweden (latitude: N 59° 37.8; longitude: E 17° 04.5). It was a first cut fertilized with 126 kg N in spring. The grass was a mixture of meadow fescue and timothy, sown 5 years earlier. The first 172 bales (Forage 1), used from August until the last 2 weeks, were cut on the 8th of June, and the next bales, used for the last 2 weeks

| Table 1 Chemical composition (g/kg DM), DM (%) and estimated digestible energy content (Mcal/kg DM) of forages fed ad libitum to 16 yearlings in training from breaking in August to December the same year |
|-----------|-----------|-----------|
| Forage 1  | Forage 2  |
| CP        | 152       | 130       |
| NDF       | 545       | 600       |
| Calcium   | 3.6       | 3.1       |
| Phosphorous| 3.2       | 2.3       |
| Magnesium | 1.2       | 1.3       |
| DM        | 56        | 61        |
| Energy    | 3.02      | 2.80      |

DM = dry matter.

Fed from August to November.

Fed in December.
Boxes except during training. Ad libitum was defined as a around the 20th of every month in October, November and December. During these days, the horses were kept in their boxes except during training. Ad libitum was defined as a minimum of 2.0 kg of haylage leftovers per 24 h. Feed samples were taken from the bales used during feed intake registrations and from ~10% of the remaining bales using a drill. Before analysis, samples were dried (60°C, 16 h) and milled. DM content was determined by drying samples at 103°C for 16 h. Chemical analysis of feed samples was performed with NIRS (FOSS, Sweden). Mineral content was analyzed by inductively coupled plasma–atomic emission spectroscopy (Spectro Flame, SPECTRO Analytical Instruments, Kleve, Germany) after digestion with nitric acid.

Body development

Body measurements were taken by the same person around the 20th of every month, except for the initial measurements, which were taken on the 29th of August. The body condition score (BCS) was evaluated according to Henneke et al. (1983) by dividing the body into back, ribs, tailhead and neck and shoulders, with each area given a score. Total BCSs were calculated as the mean of the four area scores. BW was recorded using a scale (weight indicator U-137, UNI Systems and Vågspecialisten, Skara, Sweden). Thickness of the m. longissimus dorsi and subcutaneous rump fat was measured with a DP-6600 Vet ultrasound system (Mindray Medical International, Shenzhen, China) using a 7.5 MHz, 38 mm linear probe. Measurement of the m. longissimus dorsi was performed right above the 18th rib by the first lumbar vertebra. Subcutaneous fat thickness was measured 5 cm from the middle line at croup according to Westervelt et al. (1976) (rump fat 1) and 15 cm caudal from this (rump fat 2). A mean of three measurements was calculated for each horse each time for both m. longissimus dorsi and fat thickness. Height at withers and height at croup were measured using a ruler with a precision of 0.5 cm. In horses shod with spikes, the heights were subtracted by 0.8 cm. Body length was measured from September to December with a folding ruler from the shoulder point to the point of the buttocks. Cannon bone circumference was measured using a tape measure right below the carpus at the left front leg. Hoof width, frog length and coronet circumference were registered before every trimming by the farrier. Frog length and coronet circumference were measured directly on the horse. For width measurement, the hoof was placed on a sheet of paper and a plot of the hoof was made, which was measured. Trimming was performed at ~5-week intervals.

Muscle fiber composition and glycogen content

A muscle biopsy was taken from the m. gluteus medius in December according to the method of Lindholm and Piehl (1974). The horses had not been exercised for 2 days before sampling but had spent 8 h/day in a paddock. A local ointment anesthesia of Lidocain and Prilokain (Emla®, 25 mg/g, Astra Zeneca, London, UK) was applied to the skin 10 min before the application of a nose twitch and subcutaneous injection of 100 mg Mepivacaine (Carbocaine®, 20 mg/ml, Astra Zeneca). After another 5 min, a biopsy sample was collected along a line from the tuber coxae to the tailhead at 1/3 of the distance from the tuber coxae at a fixed depth of 5 cm. Samples were rolled in talcum powder, frozen in liquid nitrogen and stored at ~80°C. The histochemical analysis of the muscle samples has been described earlier in the study by Essen-Gustavsson et al. (1983). At least 200 fibers were identified and fiber-type distribution (types I, IIA, IIB) was investigated using a morphometric computer program (Leica QWin Pro V 3.5.1) modified for muscle analyses. The content of glycogen was analyzed on freeze-dried muscle that had been dissected free from fat, blood and connective tissue. The muscle sample was then boiled for 2 h in 1 mol/l HCl and glucose was analyzed by a fluorometric method according to Lowry and Passonneau (1973).

Health

Health-related disorders that required veterinary treatment were noted in a protocol. On two occasions (October and November), the health status of each horse was evaluated by an independent veterinarian using a standardized health assessment protocol similar to the protocol described by Darenius et al. (1983) and used in the Swedish warmblood riding horse 4-year-old quality test. In those tests, equal amounts of time (10 + 10 min) were spent on orthopedic and medical inspections. In the present study, ~8 and 2 min were spent on orthopedic and medical inspection, respectively. The health assessment included: (a) remarks on hoof to back in hind legs and hoof to shoulder in front legs (number of swellings, heat and soreness, where the severity of each observation was graded from 1 to 3); (b) movements at walk and trot by hand (baseline) and after a 30-s flexion test of all joints in all four legs (for handling reasons performed only in November) where the severity of a lameness was graded 1–5; and (c) an assessment of the overall impression of the horse (graded 1 to 10, where 10 is the best health condition) including all observations above, an auscultation of lungs and heart as well as a brief inspection of hair coat, skin and mucous membranes (oral cavity and conjunctivae).

Plasma lactate and heart rate (HR)

HR was measured (Polar CS600X, Polar Electro, Finland) in October and December during and after a standardized exercise test at an oval track (5 km at a speed of ~5.6 m/s). Data were downloaded and analyzed by Polar ProTrainer.
5 Equine Edition Software (Polar Electro, Kempele, Finland).
The mean HR during the third kilometer and HR 3 min after
the exercise (end of trot) were recorded and used for further
analysis. In December, another exercise test was conducted
(5 km at a speed of −5.6 m/s; during the last 200 m
the horse was allowed to trot at fast as it could without
galloping). A blood sample was taken within 1 min after
the final speed. Blood was collected from the jugular vein
in Lithium Heparin tubes (10 ml) and stored cool until
centrifugation. After centrifuging (10 min, 2700 rpm, 920 G),
the plasma was frozen (−20°C) for later analysis. Plasma
was analyzed for lactate using an enzymatic method in a LMS
lactate analyzer (Analox Instruments, London, UK)

Statistical analyses
All variables were analyzed by ANOVA (GLM procedure in
the Statistical Analysis Systems package 9.2) using a model
including fixed effects (month and horse). Values are pre-
sented as least square means and root mean square error for
each parameter except for age, muscle glycogen content,
muscle fiber composition and plasma lactate concentrations,
which are presented as means ± s.d. Differences were con-
sidered statistically significant at P < 0.05. Tukey’s test
was used to define differences between months. Analysis
of correlations was performed on all parameters using
Pearson’s Correlations test including horse and period as
fixed effects.

Results
Feed intake and body development
DM, energy and CP intake were similar from October to
November and decreased (P < 0.05) in December (Table 2).
There was an increase (P < 0.05) in BW (+5.1 kg), total BCS
(+0.3), height at withers (+5.4 cm), height at croup
(+4.6 cm), cannon bone circumference (+9 mm) and hoof
size (hoof width +9 mm, coronet circumference +19 mm
and frog length +23 mm) from August to December (Table 2).
Body size, height at withers and BW were correlated with
several other size parameters (Table 3). The thickness of rump
fat 1 decreased from October to December (−2.0 mm,
P < 0.001), but rump fat 2 increased during the same period
(+1.2 mm, P < 0.05, Table 2). The glycogen content in the
m. gluteus medius was 532 ± 56 mmol/kg dry weight (DW) in
December. Muscle fiber-type composition was 29 ± 7% type I,
40 ± 7% type IIA and 31 ± 7% type IIB fibers.

Table 2 Daily DM, energy, CP, Ca and P intake, BW, BCS1 and body measurements in yearlings in training fed a forage-only diet ad libitum from
breaking in August to December the same year2

<table>
<thead>
<tr>
<th></th>
<th>August</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>RMSE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM intake (kg DM/100 kg BW)</td>
<td>–</td>
<td>–</td>
<td>2.8a</td>
<td>2.8a</td>
<td>2.6b</td>
<td>0.2</td>
<td>0.002</td>
</tr>
<tr>
<td>Energy intake3</td>
<td>–</td>
<td>–</td>
<td>8.40a</td>
<td>431.0a</td>
<td>354.9b</td>
<td>38.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>CP intake (g/100 kg BW)</td>
<td>–</td>
<td>–</td>
<td>428.3a</td>
<td>416.0a</td>
<td>341.9b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ca intake (g/100 kg BW)</td>
<td>–</td>
<td>–</td>
<td>16.3a</td>
<td>16.2a</td>
<td>13.5b</td>
<td>0.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>P intake (g/100 kg BW)</td>
<td>–</td>
<td>–</td>
<td>9.5a</td>
<td>9.5a</td>
<td>6.5b</td>
<td>0.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BW (kg)</td>
<td>402a</td>
<td>425b</td>
<td>431c</td>
<td>443d</td>
<td>453e</td>
<td>6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BCS whole body</td>
<td>4.6a</td>
<td>4.8ab</td>
<td>4.9b</td>
<td>4.9b</td>
<td>4.9b</td>
<td>0.2</td>
<td>0.001</td>
</tr>
<tr>
<td>BCS back</td>
<td>5.1</td>
<td>5.3</td>
<td>5.2</td>
<td>5.3</td>
<td>5.1</td>
<td>0.3</td>
<td>0.167</td>
</tr>
<tr>
<td>BCS ribs</td>
<td>4.4a</td>
<td>4.7ab</td>
<td>5.0b</td>
<td>4.8b</td>
<td>4.8b</td>
<td>0.5</td>
<td>0.010</td>
</tr>
<tr>
<td>BCS tail head</td>
<td>4.2a</td>
<td>4.5ab</td>
<td>4.6b</td>
<td>4.7b</td>
<td>4.7b</td>
<td>0.3</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>BCS shoulders</td>
<td>4.7</td>
<td>4.7</td>
<td>4.6</td>
<td>4.7</td>
<td>4.8</td>
<td>0.3</td>
<td>0.250</td>
</tr>
<tr>
<td>Rump fat thickness 14</td>
<td>–</td>
<td>2.6a</td>
<td>2.4ab</td>
<td>1.9b</td>
<td>1.9b</td>
<td>0.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Rump fat thickness 25</td>
<td>7.6ac</td>
<td>7.2a</td>
<td>8.3ac</td>
<td>8.8cd</td>
<td>8.8cd</td>
<td>0.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>m. longissimus dorsi thickness6</td>
<td>40.9</td>
<td>41.6</td>
<td>41.1</td>
<td>40.3</td>
<td>40.3</td>
<td>1.7</td>
<td>0.192</td>
</tr>
<tr>
<td>Height at withers (cm)</td>
<td>148.7b</td>
<td>150.1b</td>
<td>150.8c</td>
<td>153.3d</td>
<td>154.8e</td>
<td>0.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Height at croup (cm)</td>
<td>151.9b</td>
<td>152.9b</td>
<td>154.3b</td>
<td>155.3c</td>
<td>156.5d</td>
<td>0.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Body length (cm)</td>
<td>–</td>
<td>–</td>
<td>151.5</td>
<td>153.8</td>
<td>153.9</td>
<td>3.0</td>
<td>0.064</td>
</tr>
<tr>
<td>Cannon bone7</td>
<td>207a</td>
<td>208a</td>
<td>215b</td>
<td>216b</td>
<td>216b</td>
<td>6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hoof width8</td>
<td>114a</td>
<td>115b</td>
<td>120b</td>
<td>122bc</td>
<td>123d</td>
<td>2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Coronet</td>
<td>339a</td>
<td>346b</td>
<td>352c</td>
<td>354cd</td>
<td>358d</td>
<td>5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Frog length (mm)</td>
<td>66 ± 5a</td>
<td>76 ± 5ab</td>
<td>84 ± 4b</td>
<td>86 ± 4b</td>
<td>89 ± 4b</td>
<td>17</td>
<td>0.004</td>
</tr>
</tbody>
</table>

DM = dry matter; Ca = calcium; P = phosphorus; BCS = body condition score; RMSE = root mean standard error.
1According to Henneke et al. (1983).
2Values presented as least square means and RMSE.
3Mcal digestible energy/100 kg BW.
4Measured 5 cm from the middle line at croup (mm).
5Measured 15 cm caudal from rump fat 1 (mm).
6Measured at the first lumbar vertebra (mm).
7Circumference below carpus (mm).
8Measured at the bottom before trimming (mm).
9According to Henneke et al. (1983).
10Small letters indicate differences between months (Tukey’s test, P < 0.05).
Training
The number of training days varied between months ($P < 0.05$), but the total distance trained increased from October to December ($P < 0.05$, Table 4). There was a tendency for a reduced mean HR during the third kilometer ($P < 0.07$), and HR 3 min after exercise was significantly lower in December than in October (Table 4). The plasma lactate concentration after exercise in December was 1.7 ±1.8 mmol/l (range 0.6 to 7.6 mmol/l for all horses; range 0.6 to 2.5 for 15 horses and 7.6 mmol/l for one horse).

Health
There were no differences in total health scores, leg remarks and lameness between October and November (Table 5). During the whole study, 13 horses received veterinary treatment. Six horses had hoof-related problems, four had wounds and three horses had both hoof-related problems and wounds that required veterinary treatment. One of the wounded horses also had an esophageal impaction when fed dry pelleted lucerne. No other possible feed-related disorders or stereotypic behaviors were observed. The number of training days lost because of health-related problems was less than one per month, except during November when more than 5 days were lost (Table 5).

Muscle and exercise response correlations
HR 3 min after exercise was negatively correlated to the amount of training (Table 6), and HR during exercise was positively correlated to the percentage of type IIB fiber ($R = 0.67$, $P < 0.01$). The percentage of fiber type IIA was positively correlated to rump fat (site 2; $R = 0.62$, $P < 0.05$). Muscle fiber type I was positively correlated to BCS at the back ($R = 0.52$, $P < 0.05$), and the thickness of $m$. longissimus dorsi was positively correlated to BCS total (0.32, $P < 0.05$), BCS ribs ($R = 0.33$, $P < 0.01$) and BCS tailhead ($R = 0.28$, $P < 0.05$)

### Table 3
**Correlations between monthly body size measurements**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Height at withers</th>
<th>Body length</th>
<th>Left cannon bone circumference</th>
<th>Rump fat 1</th>
<th>Coronet circumference</th>
<th>Frog length</th>
<th>Hoof width</th>
<th>BW</th>
<th>Body condition ribs</th>
<th>Body condition tailhead</th>
<th>Body condition whole body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height at withers</td>
<td>0.92</td>
<td>0.52</td>
<td>0.55</td>
<td>−0.43</td>
<td>0.74</td>
<td>0.27</td>
<td>0.49</td>
<td>0.87</td>
<td>ns</td>
<td>ns</td>
<td>0.35</td>
</tr>
<tr>
<td>Body length</td>
<td>0.83</td>
<td>ns</td>
<td>0.57</td>
<td>−0.31</td>
<td>0.70</td>
<td>0.38</td>
<td>0.57</td>
<td>ns</td>
<td>0.31</td>
<td>ns</td>
<td>0.35</td>
</tr>
<tr>
<td>Left cannon bone circumference</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Rump fat 1</td>
<td>−0.31</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Coronet circumference</td>
<td>0.70</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Frog length</td>
<td>0.38</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Hoof width</td>
<td>0.57</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>BW</td>
<td>0.87</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Body condition ribs</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Body condition tailhead</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Body condition whole body</td>
<td>0.35</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

1For explanations see Table 2. Correlations were considered significant if $P < 0.05$, ns = no significant correlation.

### Table 4
**Amount of training and HR during and following an exercise test performed in October and December in yearlings fed a forage-only diet ad libitum from breaking in August to December**

<table>
<thead>
<tr>
<th>Metric</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>RMSE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training (days/month)</td>
<td>12.9</td>
<td>15.1</td>
<td>11.8</td>
<td>16.4</td>
<td>3.4</td>
<td>0.003</td>
</tr>
<tr>
<td>Distance (km/month)</td>
<td>32.4</td>
<td>65.1</td>
<td>103.9</td>
<td>16.8</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td>Exercise HR (beats/min)</td>
<td>158</td>
<td>148</td>
<td>14</td>
<td>14</td>
<td>0.065</td>
<td></td>
</tr>
<tr>
<td>Postexercise HR (beats/min)</td>
<td>81b</td>
<td>73b</td>
<td>8b</td>
<td>8b</td>
<td>0.026</td>
<td></td>
</tr>
</tbody>
</table>

1Values presented as least square means and RMSE.
2HR = heart rate; RMSE = root mean standard error.
3The amount was to some extent dependent on track conditions and the amount of staff available.
4Mean HR during the third km of the exercise test.
5HR 3 min after the exercise test.
6Small letters indicate differences between months (Tukey’s test, $P < 0.05$).

### Table 5
**Possible training days and lost training days per month due to health problems, total health points, sum of remarks on legs and lameness assessed by an independent veterinarian in yearlings in training fed a forage-only diet ad libitum from breaking in August to December**

<table>
<thead>
<tr>
<th>Metric</th>
<th>September</th>
<th>October</th>
<th>November</th>
<th>December</th>
<th>RMSE</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible days</td>
<td>15</td>
<td>17</td>
<td>17</td>
<td>21</td>
<td></td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Lost training days</td>
<td>0.9a</td>
<td>0.3a</td>
<td>0.2b</td>
<td>0.9a</td>
<td>3.1</td>
<td>$&lt;0.001$</td>
</tr>
<tr>
<td>Total health points</td>
<td>8.4</td>
<td>8.4</td>
<td>8.4</td>
<td>8.4</td>
<td>1.0</td>
<td>0.855</td>
</tr>
<tr>
<td>Sum of remarks on legs</td>
<td>5.5</td>
<td>5.4</td>
<td>5.4</td>
<td>5.4</td>
<td>3.9</td>
<td>0.963</td>
</tr>
<tr>
<td>Lameness on baseline</td>
<td>0.2</td>
<td>0.1</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.433</td>
</tr>
<tr>
<td>Lameness after flexion</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.271</td>
</tr>
</tbody>
</table>

1RMSE = root mean standard error.
2Values presented as least square means and RMSE.
3Days per month when training was possible because training staff was available.
4Small letters indicate differences between months (Tukey’s test, $P < 0.05$).
The reason for the lowered feed intake in December is unclear. The estimated daily energy intake in the present study was 48% higher than the requirements suggested by NRC for 18-month-old horses subjected to moderate exercise. Training days lost due to health problems were also low, generally lower than 1 day/month and in total <10%, which is lower than has been reported (27%) for 2-year-old Thoroughbred horses in training (Dyson et al., 2008). Most of the problems appeared not to be training induced but traumatic (hoof boils and wounds) and probably happened during the time that horses spent outside in the paddock. Yearling stallions housed together can be expected to play and thereby accidentally injure themselves or each other. In November, when most training days were lost due to health problems, the horses were shod with spikes, which may have caused some of the wounds that required treatment. One health problem could be linked directly to the feeding (esophageal impaction in one horse). This occurred early in the study; after this incident the pelleted lucerne was soaked in water before being fed to all horses and no further impactions were observed.

Body condition and fat

The horses had a similar BCS as described earlier for Standardbred horses in training (Gallagher et al., 1992). The positive correlation between BW and BCS total (\( R = 0.35 \)) is in agreement with the studies conducted by both Leleu and Cotrel (2006), who reported a similar correlation (\( R = 0.34 \)) in 2-year-old Standardbreds in training, and Henneke et al. (1983), who observed adult quarter horse mares (\( R = 0.50 \)). In the present study, there was no correlation between BCS total and rump fat 1, which may have been because all horses were in quite similar body condition (s.e. for BCS total = 0.05), but Henneke et al. (1983) and Leleu and Cotrel (2006) found correlations of 0.65 and 0.64, respectively, for BCS and percentage total body fat calculated using rump fat 1 and equations by Westervelt et al. (1976) and Kane et al. (1987). Using the original equation of Westerveldt et al. (\( % \text{ body fat} = 8.64 + 4.70 \times \text{rump fat 1 in cm} \)), body fat

### Table 6 Correlations between training distance and postexercise HR and other parameters in yearlings in training fed a forage-only diet ad libitum from breaking in August to December the same year

<table>
<thead>
<tr>
<th>Days with training/month</th>
<th>Distance per month</th>
<th>Postexercise HR</th>
<th>Distance/month</th>
<th>ns</th>
<th>Exercise HR</th>
<th>5</th>
<th>0.05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.53</td>
<td>-0.48</td>
<td>-</td>
<td>ns</td>
<td>0.39</td>
<td>-</td>
<td>0.38</td>
</tr>
<tr>
<td>Lost training days/month</td>
<td>0.40</td>
<td>0.67</td>
<td>ns</td>
<td>0.38</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

HR = heart rate.

1 HR 3 min after a standardized exercise test.

2 Mean HR during the third km of a standardized exercise test.

Correlations were considered significant if \( P < 0.05 \), ns = no significant correlation.
content of the horses in the present study was calculated to be 9.9%, 9.8% and 9.5% in October, November and December, respectively. This is similar to what reported by Kearns et al. (2002) in elite Standardbred horses (7% to 10% body fat). However, although Kearns et al. (2002) and Leleu and Cotrel (2006) measured rump fat 1, they used an equation developed by Kane et al. (1987), which includes a rump fat measurement more caudal than rump fat 1. Therefore, their results are difficult to interpret. Using Kane et al.’s (1987) equation and rump fat 1 (% body fat = $5.47 + 5.47 \times \text{rump fat 1 in cm}$) in the present study also resulted in comparatively low estimated body fat contents (3.9%, 3.8% and 3.5% in October, November and December, respectively). Kearns et al. (2002) also measured the thickest part in the observed position, whereas we measured at the center of the position. The discrepancy shows the importance of standardization of body fat measurements and equations. However, a body fat content around 9% in the present horses is also supported by the results of Martin-Rosset et al. (2008) who showed a high correlation ($R^2 = 0.99$) between BCS and total body fat content. Using the equation ($% \text{body fat} = 5.86 \times 0.563 \times \text{BCS}$) suggested by Martin-Rosset et al. (2008) and converted BCS (BCS 4 and 5 in the scale by Hennke et al. (1983) was converted to BCS 3 and 3.25 in the scale used by these authors (Martin-Rosset, W., pers. comm.) the body fat content of the horses in the present study would be 8.6% and 8.4% in August and September, respectively, and 7.9% in October, November and December. The relevance of the positive correlation between BCS total, but not BCS back, and thickness of $m. \text{longissimus dorsi}$ is unclear, as well as the positive correlation between rump fat (site 2) and amount of muscle fiber type IIA.

**Training**

According to the trainer, the horses underwent sufficient training to improve fitness and reach the goal of trotting 5 to 7 km at a speed of ~5–6 m/s in a vigorous way at the end of the study. This is supported by the fact that all 16 horses completed the standardized exercise test in December and showed a lowered HR during recovery and a tendency for a lowered HR during exercise. However, the racetrack surface was in October sand and in December ice and horses were shod with spikes, which may have affected the HR response to exercise. Interestingly, but not surprisingly, there was a negative correlation between training distance and HR during exercise; a positive correlation between lost training days and recovery HR and a negative correlation between the amount of training (days and distance) and recovery HR, indicating the importance of training for improved circulatory response (i.e. reduced HR during and after exercise). In addition, the lack of correlations between any of the body size parameters and HR during or after exercise implies that the reduction in HR was mainly a result of training and not due to growth. The horse that underwent the most training exercised for a total of 68 days and 271 km during the study, and the horse that underwent the least training exercised for 35 days and 132 km. Therefore, a difference in training in the range of 33 days and 139 km during a 4-month period seems to be enough to cause differences in the training response.

That a few weeks of submaximal training may improve aerobic capacity (oxygen uptake) has been shown earlier in adult horses (Knight et al., 1991). However, the response to exercise was also affected by the amount of type IIB fibers (fast twitch, low oxidative) indicated by the positive correlation with HR during exercise. Training is known to decrease the amount of IIB fibers (Essen-Gustavsson et al., 1983), and in 2-year-old Standardbreds a correlation between type IIB and plasma lactate concentration has been shown earlier (Roneus et al., 1995). A similar correlation was also observed in the present study (data not shown); however, the significance of this correlation depended on the horse with the highest plasma lactate concentration. In agreement with earlier studies on yearlings, fiber-type composition was shown to vary among the horses. The proportion of muscle fibers in the present study was in accordance with earlier observations on Standardbred yearlings by Lindholm and Piehl (1974), but the proportion of type I fibers was somewhat higher and the proportion of IIB lower than reported by Essen-Gustavsson et al. (1983). The variation in fiber types among yearlings is mostly due to hereditary factors, whereas training is an important factor known to alter fiber composition when horses get older (Essen-Gustavsson et al., 1983).

**Conclusions**

This is the first time that a holistic, long-term study on growth, training response and health in 1.5-year-old Standardbred horses on a forage-only diet has been conducted. The study indicates that yearlings in training fed high-energy forage ad libitum may: (1) grow at least as well as earlier observations on yearlings; (2) have a body condition and muscle glycogen content within the normal range of athletic horses; (3) reach a conventional exercise goal and dependent on the amount of training, showing a reduced exercise HR response; and (4) have high health scores in veterinary examination and few training days lost due to health problems.

**Acknowledgements**

The authors thank Karin Ericson, Roger Persson, Jan Halberg, Lars Åke Svärdfeldt, Johanna Svensson, Malin Connysson and the facility services and farriers at Wängen, Polar Finland, the trainers Stig H. Johansson and Thomas Uhrberg, pupils and students at Wängen and SLU, Kristina Karlström and Kristina Andersson at SLU and the breeders Staffan Nilsson (Staro International AB), Sune Svedberg (Broline International AB), Karl Erik Bender (Stuteri Palema) and Arendt Cederqvist.

**References**


Kears CF, McKeever KH, Kumagai K and Abe T 2002. Fat-free mass is related to one-mile race performance in elite standardbred horses. Veterinary Journal 163, 260–266.


Yearlings in training on a forage-only diet
