Markku Saastamoinen *Editor*

Feeding and Management of Foals and Growing Horses

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Preface

Today's horses perform a variety of roles and there are many categories of horses based on their breed, size and use. Horses are kept for many purposes and in many different circumstances and environments. Eighty per cent of the horse populations are used for hobby and leisure purposes. However, whatever the use of the horse will be, the goal is to grow sound individuals that will be durable throughout their life and will perform at its optimal level. One particular challenging stage during the early life of the foal is weaning, being a remarkable stress factor and requiring, thus, special attention to attenuate the weaning stress.

The elements of health growth and development are genetics, nutrition, exercise and housing of the foal and young horse. Thus, producing horses that will have long-term and productive careers and uses requires sound management already from conception. Like humans, horses are living today longer.

The large variety of the horses considering their breed and use makes feeding them challenging. Proper nutrition and feeding management are the main objectives to fulfil the ethological and physiological needs of the growing horse. The links between health and good dietary treatment and management practices have to be considered to increase our understanding of the needs of the growing horses and ensure their proper development and wellbeing. Gaps in nutrition and management may lead to health problems and impaired growth and performance. Special attention has to be paid on correct exercise because good nutrition alone will not optimize bone health.

It is important to ensure that evidence- and science-based knowledge is available to all horse managers and people working in the horse industry. The objective of this book is to offer latest research-based knowledge available to people involved in breeding and raising of horses. This book, authored by the leading experts on their research fields, is dealing with development, nutrition, health and wellbeing to fulfil the possible gaps in and strengthen the knowledge about management of foals and growing horses. One has to keep in mind that all horses are individuals by their temper and behaviour, growth rate, feed efficiency, etc., and that circumstances between countries are different. It is important to monitor the growth and development of the horse regularly and adjust the nutrition individually. All authors highlight that nutrition of horses shall be based on high-quality and analysed feeds.

Jokioinen, Finland Markku Saastamoinen

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Ingrid Vervuert

Abstract

Nutritional needs of the broodmare change during the different stages of reproduction. The main goals of a well-balanced diet should be adequate energy and nutrient intake such as protein, minerals and vitamins to achieve an ideal body condition and to cover all nutritional needs of the mare and raising a healthy foal. Increases in energy and nutrient requirements start already from the 5th to 8th month of gestation continuing during lactation until the milk production starts to decline. Broodmare's obesity may impact foetal metabolism, which can affect the growth and performance of the growing and adult horse. Conversely, undernutrition can cause intrauterine growth retardation of the foetus, resulting in altered development of the systems involved, which may have long-term effects on the horse that manifest during foetal, neonatal or even adult life. Colostrum is the first and the most important feed of the new-born foal providing immunoglobulins and bioactive substances. Forages should be the basis of the ration. Besides adequate energy and nutrient intake to ensure sufficient milk production, diet formulation should consider mare's feed intake behaviour and welfare such as the minimum daily forage intake, meal size, feed hygiene or water provision.

Keywords

Energy · Minerals · Vitamins · Forage · Water · Colostrum

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1.1 Introduction

Nutritional needs of the broodmare change during the different stages of reproduction. The main goal of a well-balanced diet should be an adequate energy and nutrient intake such as protein, minerals and vitamins to achieve or obtain an ideal body condition score. Under this premise, the balanced-fed broodmare will raise a healthy foal. Prolonged unbalanced rations can predispose the broodmare and foal to nutritional-related problems. Besides adequate energy and nutrient intake, diet formulation should consider mare's feed intake behaviour and welfare such as the minimum daily forage intake, meal size, feed hygiene or water provision.

1.2 Nutrient Requirements of the Maiden or Barren Mare

The gestation period in mares is typically between 330 and 345 days, approximately 11 months. Recommendations for energy, nutrient and water intake are available for broodmares; however, different countries use different national recommendations such as National Research Council (NRC) 2007 (USA), Gesellschaft für Ernährungsphysiologie (GFE) 2014 (Germany) and Martin-Rosset et al. 2015 (France). This chapter considers the different energy and nutrient recommendations for broodmares based on scientific knowledge and summarizes the main aspects of feeding pregnant and lactating mares.

It is important to highlight that the nutritional needs of broodmares change during the different stages of reproduction (Martin-Rosset et al. 2006, Coenen et al. 2011). Among other factors such as individuum, seasonality, feed availability, housing and several nutritional factors have been discussed to influence fertility and are summarized in Table 1.1.

The maiden or barren mare should be fed according to maintenance or exercise depending on the use of the mare. Occasionally, the breeding process may already start in two-year-old mares who still require energy and nutrient intake for growth (Fig. 1.1).

Several studies suggest that the mare's body condition is one of the most crucial issues which has to be considered in reproductive efficiency. There is some evidence that mare's BCS may positively correlate with the foal's birth weight: obese mares seem to have heavier foals. Maiden or barren mares which are under-conditioned (BCS < 5 on a nine-point Henneke scale, Table 1.2) have lower conception rates by lower ovulation rates and increased early embryonic death after insemination than mares which are well conditioned (BCS 5–6). Although over-feeding (>200% required energy intake) may prolong the period of annual cyclicity, it is related to several risk factors (D'Fonseca et al. 2021). Most significantly, over-conditioned maiden or barren mares (BCS > 6) may develop systemic inflammation and decreased insulin sensitivity during pregnancy which negatively affect embryonic and foetal environment by the expression of genes involved in inflammation, glucose and lipid metabolism, growth and cell stress (Robles et al. 2018). The metabolic imprinting may increase the risk of early embryonic death and may negatively affect the health of the offspring and adult horse such as a higher incidence of

Table 1.1 Energy and nutrients affecting reproduction in mares (adapted from Meyer and Klug 2001)

Item	Ovulation	Embryonal development	Foetal growth	Birth weight	Abortion
Energy ↓	Reduced	Increase in early embryonic death	No effect	No effect	No effect
Energy ↑	Increased	Equivocal results: Reduction or increase in early embryonic death	No effect	No effect	No effect
Protein ↓	Reduced	NA	NA	NA	NA
Calcium ↓	NA	NA	Reduced	Reduced	
I ↓	Suspected reduction	Suspected increase in early embryonic death	NA	NA	Suspected increase
I ↑	NA	NA	NA	NA	Suspected increase
Selenium ↓	NA	Suspected increase in early embryonic death	NA	NA	NA
Vit. A ↓	NA	Suspected increase in early embryonic death	NA	NA	NA
ß-carotene↓	Reduced	NA	NA	NA	NA

↓: Intake significant below requirement; ↑: Intake significantly higher than requirement; *NA* Not available.

osteochondrotic lesions or an impaired glucose metabolism. In conclusion, low energy stores protect maiden or barren mares to become pregnant, excessive energy stores will expose the embryo and the foetus to an inflammatory environment. Therefore, mares should have an ideal body condition (BCS 5–6) before starting with reproduction (Lawrence 2013).

In order to obtain an ideal body condition, energy intake should be adjusted at least 6–8 weeks before insemination. Protein intake should be 20% higher than the requirement for maintenance or exercise. Independent of energy intake, inadequate protein intake seemed to induce anovulation in the mare. The inclusion of protein-rich feeds with a high protein quality and a high digestibility is of great importance. In the literature, the amino acids lysine and methionine seem be the key factors in reproductive efficiency, but other essential amino acids should be considered as well although requirements are not well defined.

Minerals and vitamins should be fed according to maintenance or exercise. Both undersupply and excessive intake must be avoided. In research, special attention has been focused on the intake of beta-carotene and the ovarian function in maiden or barren mares. From literature, a daily beta-carotene intake of 0.4 mg/kg BW is recommended before insemination.

1.2.1 Practical Feeding of the Maiden and Barren Mare

The main goal of rationing should be an adequate energy intake to achieve an ideal body condition score of 5–6 before insemination. Grazing on a lush pasture is

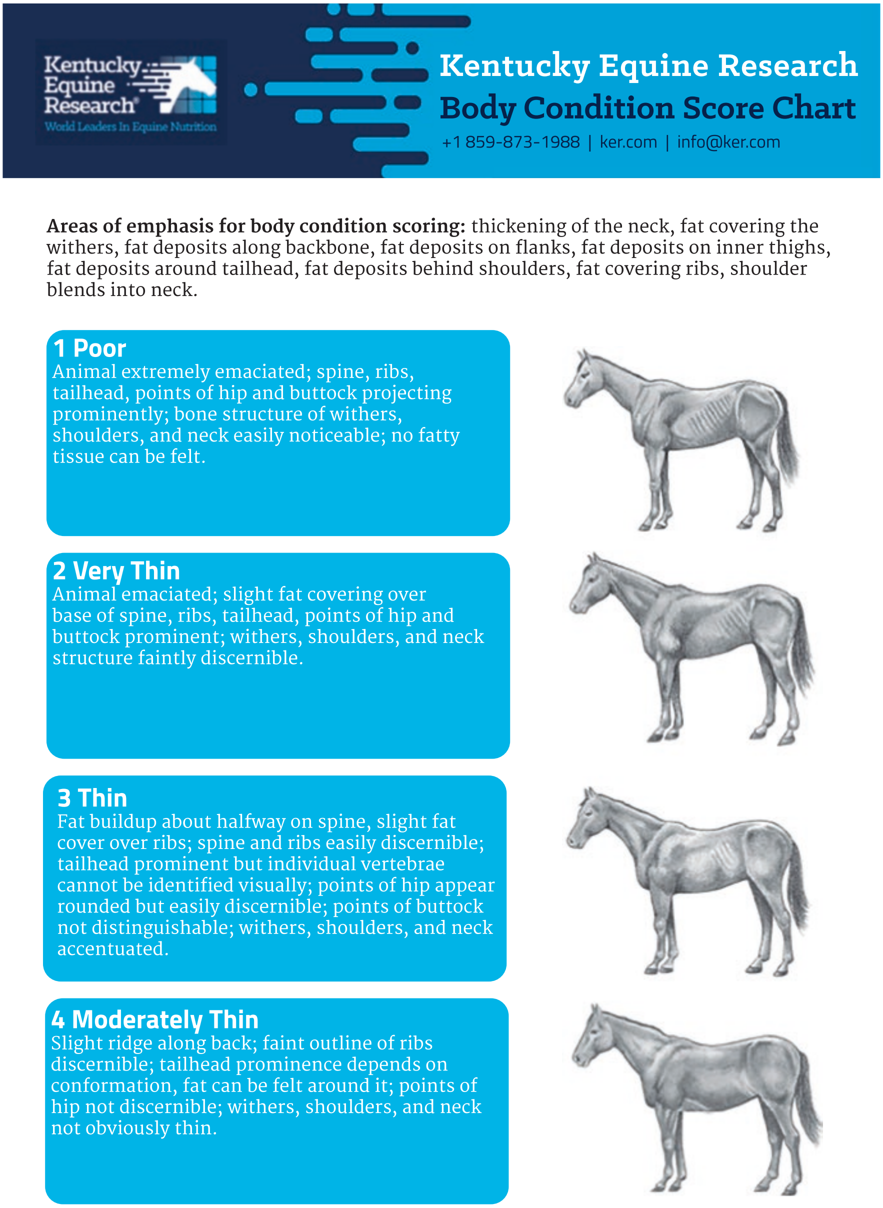

Fig. 1.1 Body condition scoring system (adapted from KER Body Condition Scoring Chart)

recommended, except for obese mares. Mares will consume fresh grass up to 2.5 to 3% of body weight (based on dry matter) and the grass intake will cover or exceed energy and protein requirements. During autumn and winter without access to pasture, preserved forages such as meadow hay or haylage are the basis of the ration.

5 Moderate
Back is flat (no crease or ridge); ribs not visually distinguishable but easily felt; fat around tailhead beginning to feel spongy; withers appear rounded over spine; shoulders and neck blend smoothly into body.

6 Moderately Fleshy
May have slight crease down back; fat over ribs fleshy/spongy; fat around tailhead soft; fat beginning to be deposited along sides of withers, behind shoulders, and along side of neck.

7 Fleshy
May have crease down back; individual ribs can be felt; but not noticeable filing between ribs with fat; fat around tailhead soft; fat deposited along withers, behind shoulders, and along neck.

8 Fat
Crease down back, difficult to feel ribs; fat around tailhead very soft; area along withers filled with fat; area behind shoulders filled with fat; noticeable thickening of neck; fat deposited along inner thighs.

9 Extremely Fat
Obvious crease down back; patchy fat appearing.

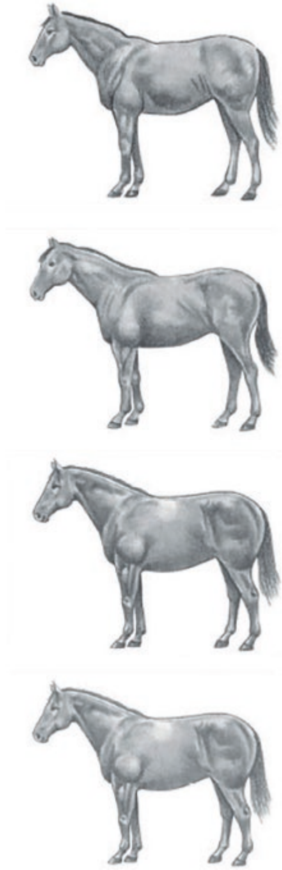

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Fig. 1.1 (continued)

The daily intake should be a minimum of 1.5–2% of body weight, based on dry matter.

Although forages constitute major part of the diet, in most cases nutrient (carbohydrates, protein, minerals, vitamins) and hygienic analyses of the fed forages are missing which is a major limitation in equine nutrition. Especially, the feed

Table 1.2 Body condition score (adapted from Henneke et al. 1983)

Condition	Neck	Withers	Shoulder	Rips	Back	Tailhead area
1. Poor (extremely emaciated, no fatty tissue can be felt)	Bone structure easily noticeable	Bone structure easily noticeable	Bone structure easily noticeable	Ribs projecting prominently	Spinous processes projecting prominently	Tailhead, pinbones and hook bones projecting prominently
2. Very thin (emaciated)	Bone structure faintly discernible	Bone structure faintly discernible	Bone structure faintly discernible	Ribs prominent	Slight fat covering over base of spinous processes; transverse processes of lumbar vertebrae feel rounded; spinous processes are prominent	Tailhead, pinbones and hook bones prominent
3. Thin	Neck accentuated	Withers accentuated	Shoulder accentuated	Slight fat cover over ribs. Ribs easily discernible	Fat built up halfway on spinous processes, but easily discernible; traverse processes cannot be felt	Tailhead prominent butindividual vertebrae cannot be visually identified; hook bones appear rounded, but are still easily discernible; pinbones notdistinguishable
4. Moderately thin	Neck not obviously thin	Withers not obviously thin	Shoulder not obviously thin	Faint outline of ribs discernible	Negative crease(peaked appearance) along back	Prominence depends on conformation; fat can be felt; hook bones not discernible
5. Moderate	Neck blends smoothly into body	Withersrounded over spinous processes	Shoulder blends smoothly into body	Ribs cannot be visually distinguished, but can be easily felt	Back is level	Fat around tailhead beginning to feel spongy

6. Moderately fleshy	Fat beginning to be deposited	Fat beginning to be deposited	Fat beginning to be deposited behind the shoulder	Fat over ribs feels spongy	May have a slight positive crease (a groove) down back	Fat around tailhead feels soft
7. Fleshy	Fat deposited along neck	Fat deposited along withers	Fat deposited behind shoulder	Individual ribs can be felt, but noticeable fat filling between ribs	May have a positive crease down the back	Fat around tailhead is soft
8. Fat	Noticeable thickening of neck	Area along withers filled with fat	Area behind shoulder filled with fat	Difficult to feel ribs	Positive crease down the back	Fat around tailhead verysoft
9. Extremely fat	Bulging fat	Bulging fat	Bulging fat	Patchy fat appearing over ribs	Obvious crease down the back; flank filled with fat	Bulging fat around tailhead

hygiene of forages should be routinely checked for grasp, smell and colour, and by microscopic evaluation for possible microscopic findings. In the case of abnormalities, further analysis such as chemical and microbial analysis or mycotoxin determination is required. Feed hygiene considers moulds and yeasts, chemical contaminations (e.g. heavy metals), poisoning plants and foreign bodies which all may be harmful to the animal's health, reproduction and growth.

If the preserved forage is low in protein, a protein-rich feed with a good protein quality (e.g. alfalfa hay or cubes, sainfoin cubes or chaff, other legumes such as pea flakes) or a commercial protein balancer are recommended to add to the diet. On the other hand, access to a lush pasture for several hours provides sufficient protein intake of a high protein quality.

Extra energy can be provided by grains such as oats or other grains; however, grain intake should be limited to a maximum of 2 kg in horses (BW of 500–600 kg) as a high starch intake will increase the risk for metabolic disorders and gastric mucosa damage. Pectin-containing feedstuffs such as beet pulp (~0.2 kg per 100 kg BW) are recommended in under-conditioned mares as pectin provides a highly fermentable substrate for the microflora in the large intestine (Coenen & Vervuert 2020). The resulting short-chain fatty acids such as acetate and propionate by microbial pectin fermentation in the large intestine are used as energetic substrates by the equine. The energy equivalent of beet pulp (based on dry matter) is similar or even higher to the energy equivalent of grains. In addition, numerous compounded feeds with low sugar and starch levels, but enriched in protein and fat, are also available on the market. Vegetable oils provide high energy levels, but they should be limited to a daily maximum amount of 100 mL per 100 kg BW to avoid microbial disturbances in the large intestine when lipid absorption capacity is exceeded in the small intestine. Under practical feeding conditions, vegetable oils should be provided in the range of 20–50 mL/100 kg BW in under-conditioned mares. As omega 3-fatty acids have anti-inflammatory properties, linseed oil is one of the preferred lipid sources.

In most cases, a commercial mineral-vitamin supplement should be added to a forage-based diet to ensure adequate mineral intake. However, mineralized salt blocks are not recommended as the adequate intake according to the requirement is uncertain and may result in deficient or excessive intake of minerals and vitamins. In most cases, mares (500–600 kg BW) fed a compound feed exceeding daily amounts of ≥1.5 kg do not need extra minerals and vitamins as compound feeds are fortified with these elements.

A salt block containing exclusively sodium chloride (NaCl) should be provided ad libitum, although salt intake by a salt block does not necessarily meet NaCl requirements, especially in exercising horses with significant sweat losses. In case of using the maiden or barren mare as a performance horse, extra NaCl in dependency of occurring sweat losses should be provided by table salt without iodine (I) and without fluorine (F).

Horses meet their beta-carotene requirement by grazing fresh green forages, whereas dehydrated forages may be deficient in beta-carotene as forage preservation will degrade beta-carotene up to 80%. Carrots include additional sources of beta-carotene, and the majority of commercial feed is fortified with beta-carotene.

Key Points

- The ideal body condition in maiden or barren mares varies between a score of 5 and 6 on a nine-point scale.
- Over- or undernutrition may negatively affect embryotic and foetal environment with consequences such as early embryonic death, birth weight or death of the offspring.
- Energy and nutrient intake should be adjusted to maintenance or exercise depending on the use of the mare; under- and oversupply of energy and nutrients should be avoided.
- Forages should be the basis of the ration, but nutrient and hygienic analyses are frequently missing which is a major limitation in equine nutrition. Both nutritional and hygienic quality have to be monitored routinely before feeding.
- A commercial mineral-vitamin supplement should be added to forage-based diets.

1.3 Nutrient Requirements of the Pregnant Mare

Nutrient recommendations in pregnant mares (Table 1.3) consider the requirements for the mare (e.g. maintenance, performance, lactation) and the needs of the embryo and foetus. Energy and nutrient requirements are assessed according to changes in weight of the conceptus (foetus and foetal adnexal tissues such as placenta and amnion), the weight changes of maternal tissues such as uterus and udder as well as changes in composition of the conceptus such as protein, fat or mineral storing. Foetal growth (see Chap. 2) can be described by growth curves using various equations. The foetus growth is slow during the first half of the gestation, and rapid foetal development occurs from day 180 to 240 of gestation to parturition (Martin-Rosset 2005). According to studies, gestational weight gain is expected to be 14–16% of the mare's initial BW.

To estimate the nutrient requirements for pregnancy, differences in digestibility of feedstuffs, metabolism and the efficiency of energy and nutrient utilization for storage in the conceptus and maternal tissues have to be considered. Several models have been developed to assess the efficiency of energy and nutrient utilization and requirements for the broodmare (NRC 2007, GFE 2014 and Martin-Rosset et al. 2015).

In early gestation, the embryo is nourished by endometrial glands secretion before starting with the placentation to the endometrium at day 35–40 up to day 150 of gestation. By placentation, foetomaternal exchanges occur by maternal-foetal blood vessels and uterine gland secretion. During this stage, the nutrient demands of the developing foetus are not yet quantified. However, nutrition and metabolism of the mare influence the uterine environment and endometrial glandular secretion already in the early life stages of embryonal and foetal development. Until the 4th month of gestation, energy and nutrient requirements of the mare are assumed to be

Table 1.3 Daily nutrient requirements of pregnant mares (500–600 kg BW, according to NRC 2007)

Item	Unit	Month of pregnancy							
		0–4	5	6	7	8	9	10	11
DE	MJ	70–84	72–86	73–87	75–90	77–93	80–97	85–101	90–108
CP	g	630–760	690–820	700–850	730–870	760–910	800–960	840–1010	890–1070
Lysine		27.1–32.5	29.5–35.3	30.3–36.3	31.3–37.6	32.7–39.2	34.3–41.1	36.2–43.4	38.4–46.1
Ca		20–24	20–24	20–24	28–34	28–34	36–43	36–43	36–43
P		14–17	14–17	14–17	20–24	20–24	26–32	26–32	26–32
Cu	mg	100–120	100–120	100–120	100–120	100–120	125–150	125–150	125–150
Zn		400–480	400–480	400–480	400–480	400–480	400–480	400–480	400–480
I		3.5–4.2	3.5–4.2	3.5–4.2	3.5–4.2	3.5–4.2	4–4.8	4–4.8	4–4.8
Se		1.0–1.2	1.0–1.2	1.0–1.2	1.0–1.2	1.0–1.2	1.0–1.2	1.0–1.2	1.0–1.2
Vit. A	IU	30,000–39,600	30,000–39,600	30,000–39,600	30,000–39,600	30,000–39,600	30,000–39,600	30,000–39,600	30,000–39,600
Vit. E		800–960	800–960	800–960	800–960	800–960	800–960	800–960	800–960

close to the requirements of maintenance, and a well-balanced diet will cover the needs of the embryo and early foetal development.

The highest foetal growth rate occurs during the third trimester of gestation, in particular the foetus gains 60% of its weight during this time period of gestation. But based on the different models to calculate energy and nutrient requirements of the pregnant mare, the increase in energy and protein requirements starts already from the 5th to 8th month of gestation, with the highest increase from the 9th month of gestation. In addition, calcium (Ca) and phosphorus (P) requirements increase from the 7th month of gestation, and these changes highlight the enormous demand of Ca and P for foetal skeletal development. In contrast, requirements for vitamins and trace elements, except for copper (Cu), do not change during gestation in comparison to maintenance. A higher Cu intake from the 9th month of gestation has been postulated as studies showed a lower risk for osteochondrotic lesions in the offspring when Cu storage was high in the foetal liver.

1.3.1 Effects of Nutrient Intake on Colostrum

Mammary glands show physical and structural changes in the last 2–4 weeks of gestation (Starbuck 2006). Around birth, the mean secretion rate of colostrum varied around 300 ml/h with a mean total secretion rate of 2.3 ± 0.5 L. Colostrum is composed of proteins, fat, carbohydrates, minerals and vitamins. Eighty percent of the protein fraction is linked to immunoglobulins such as IgG and IgA. The immunoglobulin fraction IgG is aggregated from the blood over the last 2–3 weeks of gestation, whereas IgA is synthesized by the mammary gland itself. After parturition, mean IgG levels vary around 50–70 g/L (adequate IgG levels: > 50 g/L) with significant decreasing levels already after 2–3 h after parturition. 24 h after parturition, colostrum is fully replaced by milk with low immunoglobulin levels. Besides the significant drop in IgG levels in the colostrum, IgG absorption in the small intestine declines to almost zero by 12–24 h after birth. On the contrary, the highest absorption rate of immunoglobulins occurs in the first 4–6 h of foal's life. Colostrum also contains immune cells (e.g. leucocytes), complement, bioactive substances such as lysozyme or lactoferrin, growth factors and hormones. Bioactive substances modulate metabolic processes such as the maturation of the gastrointestinal tract and meconium excretion in foals. Besides the role to provide immunoglobulins and bioactive substances, colostrum is the first and the most important feed of the new-born foal (Table 1.5).

The amount and composition of the colostrum depend on several factors. Appropriate nutrition, housing conditions considering the welfare and specific needs of the animal as well as health management (e.g. vaccination status) provide the basis of adequate colostrum quality and volume. Maiden and aged horses (over 15 years) produce lower immunoglobulin levels. Primiparous mares tend to have lower quantities of colostrum. The impact of feeding selenium (Se) or Vitamin E above requirement or the supplementation of omega-3 fatty acids to improve colostrum quality reveals equivocal results in the literature. Therefore, according to the current knowledge feeding Se, Vitamin E or other nutrients above requirement is lacking scientific evidence.

1.3.2 Practical Feeding

Until the 4th month of gestation, ration formulation can be adapted from maiden or barren mare. As energy and nutrient requirement already increase from the 5th month of gestation, daily forage intake should be a minimum of 2% of body weight on DM basis. However, special attention must be paid to the forage quality (pasture grass, dehydrated forages) as energy and protein requirements will be only adequately covered under the premise of good forage quality. A close sensory control of hygienic quality and nutrient analyses of the fed forages is recommended to implement these data in appropriate feeding guidelines.

The increase in energy and protein requirements in late gestation (9th–11th month of gestation) can be either covered by 12–24-h access to pasture grass or by feeding alfalfa hay (2% of BW, based on dry matter) as both feedstuffs are rich in energy and protein. As season may limit access to pasture grass or alfalfa hay is not available, protein-rich feed such as soybean, pea flakes, rapeseed meal, lupin or commercial feeds fortified with protein should be added to the diet. The level of inclusion of protein-rich feedstuffs into the diet relies on the protein intake by forages, highlighting the necessity of forage nutrient analysis.

As dry matter intake might be reduced in the last month of pregnancy or if good quality forages are limited, energy intake may become a matter of concern, especially in pony breeds. Extra energy can be provided by grains, vegetable oils or beet pulp (see Sect. 1.3). Much attention has been paid to the negative consequence of starch intake also in pregnant mares among other horses. Research shows that excessive starch intake has a negative impact on metabolic and skeletal health in the offspring. Furthermore, a high starch intake may increase the risk for gastric mucosa damage in the mare; therefore, starchy feed such as grains should be limited in the ration up to a maximum level of 2 kg per day (500–600 kg BW). As Ca and P requirements increase threefold during the last trimester of gestation, a commercial mineral-vitamin supplement with fortified Ca (12%) and P (6%) levels should be added to the diet, especially in those diets which do not include alfalfa or clover (mixtures) as a forage source. A salt block containing exclusively NaCl should be provided ad libitum. As most mares will not be exercised in the last trimester of gestation, extra salt (NaCl) should only be added in case of sweat losses under hot climatic conditions.

Numerous energy and protein-dense compound feed claimed for pregnant mares are available on the market which can be fed to substitute grains and a protein balancer. In most cases, mares (500–600 kg BW) fed a compound feed exceeding daily amounts of ≥1.5–2 kg do not need extra minerals and vitamins as compound feeds are supplemented with these nutrients.

The optimal body condition score needs to define in pregnant mare, but most data suggest that a score of 6 in the last trimester may provide sufficient energy stores to enter the demanding period of lactation.

Key Points

- Until the 4th month of gestation, energy and nutrient requirements of the mare are assumed to be close to the requirements according to maintenance.
- Gestational weight gain is expected to be 14–16% of the mare's initial BW.
- Increase in energy and nutrient requirements start already from the 5th to 8th month of gestation, but with the highest increase from the 9th month of gestation.
- Colostrum provides immunoglobulins and bioactive substances.
- Colostrum is the first and the most important feed of the new-born foal.

1.4 Nutrient Requirements of the Lactating Mare

The lactation period is a challenging period in mare's life. Requirements for lactation result from the body weight of the mare, milk yield and milk composition (Table 1.4).

Milk yield varies around 3% of BW in large breeds and 4% of BW in pony breeds, but a high variation has been reported in the literature. In the past, it has been postulated that peak lactation occurs in the 3. month of lactation, but recent data suggest that peak lactation already appears at day 30 of lactation. The assumption of peak lactation in the transition between the end of the first and second month of lactation seems reasonable as this period is linked to the highest BW gain of the foals and in consequence foals' highest energy and nutrient demands. According to recent data, milk yield may be estimated from the following equation:

$$\text{Milk yield}\left(\text{g} / \text{kg}^{0.82}\,\text{BW}\right) = 66\text{d}^{0.1727}\,\text{e}^{?0.00539\text{d}} \qquad \left(\text{d} = \text{day of lactation}\right)$$

Table 1.4 Daily nutrient requirements of lactating mares (500–600 kg BW, according to NRC 2007)

Item	Unit	1st month	3rd month	5th month
DE	MJ	133–160	128–154	118–142
CP	g	1.54–1.84	1.47–1.76	1.33–1.6
Lysine		85–102	80–96.4	71–85.5
Ca		59–71	55.9–67.1	39.5–47.4
P		38.3–46	38.1–43.2	24.7–29.6
Cu	mg	125–150	125–150	125–150
Zn		500–600	500–600	500–600
I		4.4–5.3	4.4–5.3	4.4–5.3
Se		1.25–1.5	1.25–1.5	1.25–1.5
Vit. A	IU	30,000–36,000	30,000–36,000	30,000–36,000
Vit. E		1000–1200	1000–1200	1000–1200

Table 1.5 Colostrum and milk composition in mares (according to Coenen et al. 2011, extensive review of the data)

Nutrient	Unit per kg	Colostrum	Milk (mean)	Milk (day of lactation)				
				30	60	90	120	150
Gross energy	MJ	3.276	2.150	[1]	[1]	[1]	[1]	[1]
Ash	g	6	4.2	[1]	[1]	[1]	[1]	[1]
Fat		18.8	13.9	[1]	[1]	[1]	[1]	[1]
Lactose		48.3	64.6	[1]	[1]	[1]	[1]	[1]
Protein		79.8	23.2	23.4	21.1	19.8	18.8	18.1
Ca	mg	874	1033	995	870	796	744	704
P		683	604	534	449	400	365	338
Mg		203	73	74	63	57	52	49
Na		424	183	[1]	[1]	[1]	[1]	[1]
K		1084	666	[1]	[1]	[1]	[1]	[1]
Cl		NA	278	[1]	[1]	[1]	[1]	[1]
S		1025	241	[1]	[1]	[1]	[1]	[1]
Cu		1.6	0.29	[1]	[1]	[1]	[1]	[1]
Zn		4.4	2.2	[1]	[1]	[1]	[1]	[1]
Fe		0.9	0.7	[1]	[1]	[1]	[1]	[1]
Mn		0.045	0.039	[1]	[1]	[1]	[1]	[1]
Se		0.093	0.032	[1]	[1]	[1]	[1]	[1]
Vit. A	IU	2600	2077	[1]	[1]	[1]	[1]	[1]
Vit. D3		216	128	[1]	[1]	[1]	[1]	[1]
Vit. E	mg	1.34	1.13	[1]	[1]	[1]	[1]	[1]
Vit. K		0.04	0.03	[1]	[1]	[1]	[1]	[1]
Vit. C		25	109	[1]	[1]	[1]	[1]	[1]
Thiamine		380	209	[1]	[1]	[1]	[1]	[1]
Riboflavin		1.4	0.35	[1]	[1]	[1]	[1]	[1]
Niacin		1.6	0.62	[1]	[1]	[1]	[1]	[1]
Pantothenic acid		7.5	0.33	[1]	[1]	[1]	[1]	[1]

[1]no changes during day of lactation, *NA* not available

Milk composition varies during the lactation period with decreases in protein, amino acids, Ca and P, but without any significant changes in lactose, fat or trace elements and vitamins (Tables 1.5 and 1.6).

Besides milk yield and milk composition, additional considerations are necessary to extrapolate the data into energy requirements, namely differences in digestibility of feedstuffs, metabolism of nutrients such as fat, protein or carbohydrates and the efficiency to convert digestible or metabolizable energy into milk energy. Similar adjustments have been considered for protein and amino acids to define requirements.

Furthermore, research suggests that lactation may increase mare's maintenance requirement for energy and protein as basal metabolism such as feed intake, digestion processes and changes in maternal behaviour are higher in lactating mares than in horses under maintenance conditions.

Table 1.6 Amino acid levels in mare's colostrum and milk (according to Coenen et al. 2011)

Nutrient	Unit per kg	Colostrum	Milk (mean)	Milk day of lactation				
				30	60	90	120	150
Leucine	g	6.93	2.15	2.16	1.95	1.83	1.74	1.67
Lysine		6.87	1.72	1.73	1.56	1.47	1.40	1.34
Threonine		5.5	0.98	0.99	0.89	0.83	0.79	0.76
Valine		4.18	1.27	1.28	1.15	1.08	1.03	0.99
Phenylalanine		3.58	1.00	1.01	0.91	0.85	0.81	0,78
Arginine		3.44	1.19	1.20	1.08	1.01	0.96	0.92
Histidine		3.03	0.65	0.65	0.59	0.55	0.53	0.51
Isoleucine		2.40	1.04	1.05	0.94	0.88	0.84	0.81
Tryptophan		1.12	0.55	0.56	0.50	0.47	0.45	0.43
Methionine		1.05	0.50	0.51	0.46	0.43	0.41	0.39

Diets which do not meet the requirements will result in the utilization of endogenous body stores of the mare to maintain milk yield and nutrient composition. Consequently, body weight losses will occur in the mare, but foal's development remained unchanged in the first weeks of life by a constant milk yield and unchanged milk composition. However, longer periods of energy or protein deprivation in the lactating mare may result in growth retardation in the offspring as milk yield will decrease. Likewise, the over-supply of energy and protein to the lactating mare does not have consequences of foal's development. It is speculated that excessive energy and protein intake of the mare may result in a higher milk yield but less energy dense. The mineral composition of the mare's milk is less influenced by dietary modifications except for Se, and probably for I. For example, besides a high dietary Cu, Zn, Fe or Mn intake, these trace elements remained very low in mare's milk. On the other hand, a high Se intake of the mare will increase Se levels in mare's milk. Although data are missing, the same supplementation is assumed for I by a high I intake.

However little, data are available about the effects of different vitamin intakes and the corresponding vitamin levels in mare's milk. Beta-carotene supplementation (1000 mg per day) to mares (470–560 kg BW) from 2 weeks before foaling until 6 weeks after parturition increased β-carotene concentrations in mares' plasma and milk. The daily oral supplementation of 2500 IU RRR-alpha-tocopherol during the last 4 weeks of gestation increased alpha-tocopherol content in mare's milk and foal's plasma, compared to a control group which was fed with Vitamin E below requirements.

1.4.1 Practical Feeding

Lactation is a demanding situation as energy and protein requirements increase significantly compared to gestation. Furthermore, most broodmares are inseminated during the lactation period, usually in the first 30 days after parturition. Daily dry matter intake is high in lactating mares and varies up to 3 to 4% of BW. Because of the high dry matter intake capacity, the high energy and protein needs can be covered in whole or in part by forage-based diets. Parturition during springtime offers the possibility for whole-day pasturing of the mare and her offspring. Lush pasture grass is rich in energy and protein. Considering a minimum dry matter intake of 3% of BW, a 600 kg mare will consume 18 kg dry matter or ~ 70 kg of grass based on fresh matter. In general, grass intake will cover energy and protein requirements of the lactating mare under the premise that grass is sufficiently available on the pasture. Alfalfa hay or early cut meadow hay are alternative forage sources with high to medium energy and protein levels. Extra energy can be provided by grains, vegetable oils or beet pulp (see Sect. 1.3). In addition, protein-rich feedstuffs such as alfalfa cubes, soybean and rapeseed meal, pea flakes, lupin or sainfoin are available for equine nutrition. As Ca and P requirements increase severalfold during lactation, a commercial mineral-vitamin supplement with fortified Ca (12%) and P (6%) levels should be added to the diet, especially in those diets which do not include alfalfa (or other legume species) as a forage source. Energy and protein-dense compound feed claimed for lactating mares are available on the market which can be fed to substitute grains and a protein balancer. In most cases, mares (500–600 kg BW) fed a compound feed exceeding daily amounts of ≥2.5–3 kg do not need extra minerals and vitamins as compound feeds are supplemented with these elements. A salt block containing exclusively NaCl should be provided ad libitum. However, some foals tend to develop an excessive licking from the salt block; in those cases, the salt block should be replaced by table salt without I and without F (2–5 g/100 kg BW) which should be mixed in the mare's crib feed.

The optimal body condition score needs to define in lactating mare, but data suggest that a score of 5–6 may provide sufficient energy stores during lactation period.

Key Points

- Lactation is a demanding situation as energy and protein requirements increase significantly in comparison to gestation.
- Milk yield varies around 3% of BW in large breeds and 4% of BW in pony breeds.
- Peak lactation occurs in the transition between the end of the first and second month of lactation.
- Milk composition varies during lactation period with decreases in protein, amino acids, Ca and P, but without any significant changes in lactose, fat or trace elements and vitamins.

1.5 Feeding of the Neo-Natal and Orphaned Foal

1.5.1 Neo-Natal Foal

Birth is one of the most stressful periods for a foal. A foal weighs around 10% of its final body weight at birth (see Chap. 2) but is already fully developed with one of the most advanced skeletons in new-born mammals. In contrast, energy stores such

Table 1.7 Assessment of colostrum quality (according to Knottenbelt et al. 2004)

Parameter	Outcome
Colour	Yellow
Consistency	Thick, sticky
IgG levels	≥70 g/L
Specific gravidity by colostrometer	≥1.065
Sugar refractometry (BRIX type)	≥20%

as liver glycogen stores are minimal when compared to neonates of other species Ousey (2003). New-born foals that fail to ingest colostrum within the first hours of their life will become hypoglycaemic, hypovolaemic and hypothermic which is a life-threatening situation. Furthermore, a delay in colostrum intake will significantly reduce immunoglobulin absorption which increases the risk of infection.

First colostrum intake should be at the latest within 2–4 h after the birth. Some studies showed that foal's overall survival rate is higher when colostrum is provided by milking the mare's colostrum and application by a bottle (200–250 mL) within the first 30–120 min postpartum. The volume of colostrum which should be ingested by the suckling foal depends significantly on the milk quality (Table 1.7) and the foal's capacity to nurse. Ideally, 1.5–2 L of an adequate colostrum should be ingested within the first 4–6 h postpartum in a new-born foal of 50–60 kg BW. In total, foals consume about 15% of their BW as colostrum/milk during the first 24 h postpartum (approximately 8 L for a 50 kg foal).

Colostrum also acts as a laxative and stimulator of the gastrocolonic reflex; most foals will start to evacuate meconium (composed of intestinal secretions, swallowed amniotic fluid and cellular debris) within 1–2 h after birth, shortly after the ingestion of colostrum.

Colostrum quality should be checked by refractometer or colostrometer before the first suck (Table 1.7). In case of low IgG colostrum levels or missing colostrum by several conditions such as death of the mare, agalactia, or rejection of the foal by its dam, supplementation with donor colostrum is necessary to prevent failure or partial failure of passive transfer of immunity. Most stud farms collect and store colostrum by milking colostrum in highly productive mares within 2 h postpartum. Colostrum for a colostrum bank should have IgG levels ≥70 g/L and a specific gravidity ≥1.065. Storage in a freezer at −20 °C will sufficiently preserve IgG levels in the colostrum for 12 months. Furthermore, several charities also provide colostrum banks for emergency situations. However, farm colostrum banks are most specific with respect to antibodies to antigens or infection. Although equine colostrum is ideal, bovine colostrum might be an option in case of emergencies. An adequate colostrum intake should be verified by analysing foal's serum IgG levels 12 h postnatal by rapid testing methods. In case of low IgG levels, plasma therapy preferably from a donor adult gelding kept on the same stud farm for at least some months is necessary as the new-born foal is immunoincompetent. By 18–20 h postpartum, intestinal absorption of colostral antibodies is declining to zero; therefore, IV plasma therapy is requested.

In the following, energy and nutrient requirements of the healthy new-born foals are covered by suckling up to 5–7 times per hour consuming up to 80–100 mL per suck within the first week of life (approximately 12–15 L for a 50–60 kg foal, Ousey et al. 1996). Studies show that each suckling bout lasts less than 2 min. Suckling frequency drops down during growth to approximately one suck per hour at a foal's age of 6 months. Besides suckling, healthy foals start nibbling solid feed already in the first days of age, but with significant amounts from about 3 weeks of life. Information about nutrient requirements and feeding practice in foals are given in Chap. 3.

1.5.2 Fostering

The management of an orphaned foal depends on the age at which the offspring loses its dam. A foster mare is an idle solution in foals younger than 2 months. Gentle and calm mares which have already raised several foals may exhibit preferential good maternal behaviour to orphan foals.

Assisted fostering by an experienced person may take several days, and several aspects should be considered as summarized in Table 1.8.

In case of successful fostering, the stage of lactation of the foster mare has to be considered as vitamin and mineral supplementation is recommended in foals from mare's third month of lactation.

1.5.3 Hand Rearing

Orphaned foals can be hand-fed by equine milk replacers which are offered by several feed companies. Equine milk replacer should contain 22% crude protein, 15% crude fat and less than 0.5% of fibre to mimic crude nutrients in mare's

Table 1.8 Techniques for fostering foals (modified by Dini and Deals 2021, Stoneham 2013, Knottenbelt et al. 2004)

Orphan foal	Method	Foster mare	Method
	Withhold milk for 1–2 h prior to introduction to the foster mare		Foal died in the last 24–48 h
	Covering the foal with the milk of the foster mare		Already in lactation for a few days
			Similar adult size between mare and orphan foal
			Induction of lactation by dopamine antagonist therapy (domperidone or sulpiride)
			Hand grazing is preferred for the first introduction with the orphan foal
			Easy access to food such as forage

milk. Protein sources should consist of by-products from milk processing such as skimmed milk, casein or whey. Additionally, milk replacers are fortified with minerals and vitamins to cover foal's nutrient requirements. In emergencies, either goat's milk or cow's semi-skimmed milk (2% of fat) with the addition of 20 g/L dextrose can be used as short-term alternatives. Manufacturers of equine milk replacers provide guidelines on quantities and concentrations of milk replacer to be fed to the orphan foal. However, the intake of milk replacer should be gradually introduced over the first few days: 10–15% of BW in the first week, and subsequently up to 25% of BW. Thus, monitoring the weight and growth of the foal is necessary to avoid too fast growth. In the new-born foal, bottle feeding is recommended, but orphan foals should be adapted to a bucket as soon as possible. Hand-reared foals fed by a bottle may develop much more behavioural problems than bucket-fed foals as hand-rearing by bottle increases the human-foal bonding.

One study (Stoneham et al. 2017) recommended that foals under 2 days of age should be fed hourly, and subsequently every 2 h for a further 12 days. Subsequently, the interval and milk volume can be increased gradually from the third week of life. Two to four weeks postpartum, a frequency of six meals seems to be tolerated without digestive disorders in most orphan foals. In older foals which already consume forage and creep feed, total daily amount of milk replacer up to 25% of BW can be provided into 3–5 meals without health issues such as diarrhoea. In general, milk replacer should be provided to the orphan foal at least until the third month of age, depending on the voluntary intake of forages and creep feed.

In line with mare-reared foals, grass or a good quality meadow hay should be provided since the first day of foal's life. One-week postpartum, commercial creep feed can be offered to the orphan foal, fed individually. Weaning at 3–4 months of age is possible in case of consuming sufficient forage such as grass by grazing or meadow hay and a daily minimum intake of 1 kg (e.g. Warmblooded foals) of a compound feed labelled for growing foals (see Chap. 3).

As stated above, regular monitoring of body weight is essential. Similar growth rates and body condition scores can be expected in hand-reared foals, but hand-reared foals tend to grow more rapidly than those foals reared by their dam.

Key Points

- Foals need a high-quality colostrum within the first 4–6 h postnatal.
- Higher survival rates in foals when first colostrum intake is provided by a bottle (200–250 mL) within the first 30–120 min.
- Colostrum quality should be checked by refractometer or colostrometer before the first suck.
- Equine milk replacers are commercially available by several feed companies.
- Foster mares or hand-feeding.
- Monitor growth rates of the foals.

1.6 Water Intake

Fresh clean water should be available ad libitum to the broodmare and foals. Daily water intake is significantly influenced by the type of diet, nutrient intake, exercise, ambient temperature, water temperature, individual factors and others. For example, water intake is higher when horses are fed a forage-based diet than adding grain to the diet.

According to studies, the mean daily water intake of a healthy horse under maintenance ranged from 40 to 67 ml/kg BW under thermoneutral conditions (see Chaps. 3 and 5). Pregnancy does not increase water needs in comparison to maintenance. Absolute water intake remained constant despite increasing BW during pregnancy. During lactation, water intake will increase by 30–60% to compensate water losses by milk. Additionally, water intake will increase by a higher dry matter intake of the lactating mares than during maintenance conditions by a relation of ~3 L water per kg dry matter intake.

Horses prefer to drink water from a bucket rather than from an automatic water dispenser. In case of a low water intake, water can be fortified with small amounts of sweet feed (e.g. 100–200 g compound feed in 20 L water) as horses prefer sweet feed-flavoured water compared with plain water.

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Growth and Development of the Horse

2

Maria João Fradinho, Markku Saastamoinen, and Véronique Julliand

Abstract

The growth and development are influenced by heredity, gender, nutrition, and exercise. The growth rate of a foal is related to age and delays smoothly when the foals become older. Nutrition plays a major role among the environmental factors that influence growth and development. Foals that grow very fast are at increased risk of developmental orthopedic disease (DOD). Moderate growth rates may be preferred to minimize bone abnormalities in young horses. In addition, regular and plenty of exercise promote healthy growth and bone formation of young horses. The increase in total intestinal length is the greatest during the most rapid growth period of the foal, weeks 1 to 4. A relatively large decrease in small intestinal length and great increase in the large intestine happen between 1 and 6 months of age when consumption of forage is increasing. The capacity of digesting structural carbohydrates through the suckling period is increasing and is fully competent around the time of weaning. The foal can degrade carbohydrates equivalent to that measured in adults from 1 month of age, and the nutrient digestibility values of younger horses are very similar to those observed in mature horses.

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Growth rate · Growth modeling · Digestive tract

2.1 Introduction

Breeders and trainers need to recognize the factors that affect the horse's growth and development, as well as the critical stages of these phenomena, in order to individually feed and train safely a young equine athlete. In certain types of sport, the athletic demands that are put on young, still-growing horses require to work them well above light exercise level. The most common breeds starting exercise early are those used mainly in the racing industry (e.g., Thoroughbreds, Arabians, Standardbreds, cold-blooded trotters, as well as quarter horses). Training a growing horse at a relatively young age when its development is not finished may predispose it to orthopedic injuries. Indeed, its skeleton is not yet matured, and the ability of its musculoskeletal system to adapt rapidly to the increased training load is critical.

2.2 Growth and Development

Growth refers to an increase in the live weight and body dimensions of an animal until adulthood is reached. At a cellular level, growth is due to an increase in the number and size of cells, as well as an increase of a layer of extracellular connective tissue. Growth rate is regulated by genetic factors, i.e., breed and individual differences. The range of heritability of growth and size measures is wide (0.22–0.88) and, depending on the body segment, can be quite high (e.g., height at withers). The expression of growth is also influenced by the environment. Among environmental factors, breeders' goals and local management, including feeding practices, have been shown to have a large influence on the lifetime growth pattern of the horse.

Development is the change in the structure, form, and proportions of the body, that is, the formation of the body and the development of its functions. At its most basic level, development involves the coordinated regulation of cell proliferation, cell death (apoptosis), cell migration, and differentiation. Changes in the proportions of the body mean that different parts have different rates of growth. In trotters and race horses, the age at the beginning of breaking, training, and competition may reflect its maturity. Based on these parameters, colts develop faster than fillies, but the effect of gender on development depends on the breed of the horse and increases as the foals get older.

In horses, like in other mammals, growth and development occur simultaneously, and animals grow and develop until they reach a certain stable point, i.e., adulthood. A strong genetic relationship (0.69–0.93) has been found between growth and rate of development in different growth periods. The development of horses can therefore be monitored by measuring their growth. A rapid increase in the length and size of various intestinal segments is associated with periods of rapid body weight gain.

The growth rate (usually measured by live weight expressed as mass unit per day) is influenced by age and delays smoothly when the foals become older. From conception to maturity, the pattern of equine growth can generally be described as a sigmoid curve. However, body weight (BW) and parameters that are more related to physical condition (e.g., chest width) show large variation in horses still growing. BW gain reflects generally the growth of all tissues. In turn, development of height at withers (HW), which is also applied for monitoring growth, is a measure of skeletal growth.

2.2.1 Growth and Development before Birth

Several equations (power, exponential, and polynomial models) were proposed for predicting BW of the fetus from the day of gestation. During the first half of the gestation period, there is only a small increase in the weight of the fetus. The bigger increase in weight (around 75%) is observed in the last third of gestation whatever the model used (Fig 2.1A). The development in body length observed in Thoroughbred (aborted and stillborn fetus) and measured as crown-rump length appears to precede the increase in body mass and seems to be steadier from the beginning to the end of the gestation period (Fig 2.1B).

Fetal growth and development are influenced by maternal size. Studies based on crosses between horse breeds of different sizes showed that fetal growth can be either enhanced above or restricted below the normal genetic potential for the breed by varying maternal size. The rate and extent of fetal growth are also influenced by the area of placental interface, and birth weight is related with the mass, gross area, and volume of placenta.

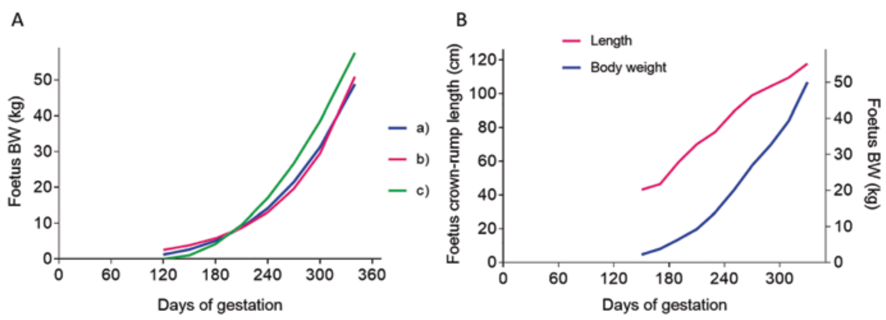

Fig. 2.1 (**A**) Modeling of fetal body weight during gestation, considering foal birth weight as 10% of the mare body weight after foaling, and mare body weight as 500 kg. Equations: (a) Fetal weight (as percent of birth weight) = $1 \times 10^{-7} X^{3.5512}$ (NRC 2007); (b) Fetal weight (as percent of birth weight) = $e^{0.0136 X}$ (Coenen 2001); (c) Fetal weight (kg) = $17.38–0.2885 X + 0.001197 X^2$ (Martin-Rosset et al. 2015) X = days of gestation. (**B**) Fetal growth observed in Thoroughbred (mean crown-rump length and body weight from 150 days to term of gestation (adapted from Platt 1978)

2.2.2 Growth and Development from Birth to Adulthood

When compared to newborns from other species, the foal seems to be more advanced in terms of growth. At birth, foals from light breeds (which includes most of the saddle horses) reach an average of 10% of their adult BW and 60% of their final withers height (HW) (Table 2.1).

During the first months after birth, growth rates are very high. For example, average daily gains (ADG) of 1.443 kg/day and 1.233 kg/day were observed, respectively, in Thoroughbred and in a group of Anglo-Arab and "Selle Français" foals during the first month of life.

The weaning takes place usually between 4.5 and 6 months. At 6 months of age, the foal (of various breeds) has achieved approximately 85% of its HW and 45% of BW. After this age and depending on the breed and management conditions, ADG progressively declines until maturity.

The average percentages observed for HW and BW at 12 months of age for various breeds are, respectively, 90 and 65, 95 and 75 at 18 months, and 95 and 90 at 24 months. At the age of 18 months, when breaking and training usually begin, Thoroughbreds, Standardbreds, and coldblooded trotters have achieved approximately 95% and 75–80% of their mature HW and BW, respectively (Fig. 2.2).

The high percentages of mature HW observed from very young ages reflect the earlier development of the skeletal tissue. In fact, allometric coefficients obtained from the comparative slaughter method showed that bone, muscle, and adipose tissue develop chronologically in this order, being respectively 0.74, 1.13, and 1.41. Moreover, considering different skeletal segments in the limbs, growth plates close earlier in the bones of the extremities (e.g., metacarpus) in relation to other bones, and occurs from ground up: the growth plates in the lower limbs close earliest, around 9–11 months of age, the knees and hocks around 24 months, and the shoulders and stifles usually in the third year. In Chap. 6, the timing of the beginning of training relative to the closure of growth plates is discussed in detail.

Table 2.1 Body weight and height at withers of newborn foals from different saddle breeds

BW (kg)	HW (cm)	Breed	Source
54–58	102–103	Thoroughbred	Kavazis and Ott (2003); Brown-Douglas et al. (2005); Pagan et al. (2006); Elliot et al. (2009)
52	99.4	Finnhorse	Saastamoinen (1990)
46	96.7	Arabian	Çilek (2009)
57	–	Hanoverian	Vervuert et al. (2005)
53–55	–	Anglo-Arab and "Selle français"	Bigot et al. (1988); Heugebaert et al. (2010)
52	–	French trotter	Heugebaert et al. (2010)
53	100	Standardbred trotter	Sandgren et al. (1993))
52	100	Lusitano	Fradinho et al. (2016)
38	90	Icelandic	Skúlason (2010)
–	93	Mangalarga Marchador	Cabral et al. (2004)

BW body weight; *HW* height at withers

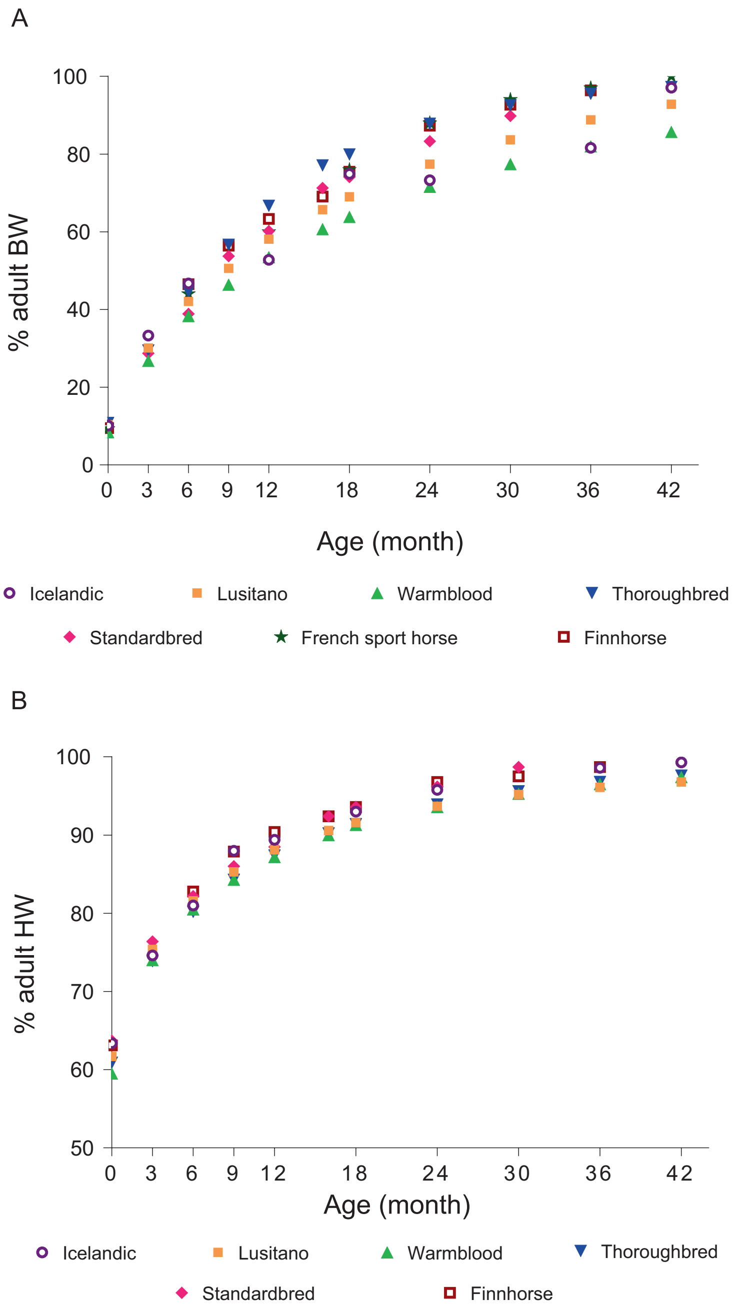

Fig. 2.2 Proportions (%) of mature body weight (**a**) and height at withers (**b**) at standard ages for different horse breeds

The growth and development of the horse to maturity usually continue to the age of 4 to 6 years, depending on the breed of the horse. Initially, the horse increases in height and later in width and depth. Bone growth in a horse usually ceases at the age of 5, but growth in some details of the body may continue even after this age. At this stage, the growth intensity of the horse's BW and heart girth is higher than that of other measures. Height measures and cannon bone circumference have on average the lowest growth intensity until maturity.

Foals that grow very fast are at increased risk of DOD. Factors affecting the risk for bone growth disorders are breed, conformation, husbandry methods, and housing practices applied during the most critical growth period during pre- and post-weaning. Also seasonal growth spurts may alter the foals to abnormal bone development. Slower growth has been observed in winter than in spring and summer, when growth accelerates on pastures. Modest growth rates may be preferred to minimize bone abnormalities in young horses. However, it is unlikely that an absolutely smooth growth curve can be achieved because of many individual (genetic) and environmental (nutrition, moving, housing system, etc.) factors affecting the body growth and development.

2.3 Factors Affecting Growth and Development

2.3.1 Heredity

Growth and development are naturally determined by genetic factors. The individual genetic effect on body size and live weight is high, and huge differences can be found from small ponies to draft horse breeds (e.g., less than 150 kg in the Miniature horse or Shetland Ponies to 1100 kg in the Shire breed). Estimated heritability coefficients (h^2) for morphologic traits vary according to the breed and to body size parameter, being particularly high for longitudinal segments such as height at withers. In literature reported, h^2 values for HW range from 0.25 to higher than 0.80 depending on the breed. Heritability estimates for BW in growing horses vary a lot (0.13–0.90).

Genetic differences become more pronounced at the end of growth than at the beginning, when feeding practices and other environmental factors have a major impact on foals' growth. Growth rate (and the protein content of the gain) is decreasing with increasing age, but those horses which grow faster during their first year of life show slower growth during the later growth periods. The preference for large size in certain selection programs may lead to rapid growth in the first year of the foal's life, and vice versa, as there are quite high positive correlations between the growth rate of the first year of life and the adult size. In addition, also the gender of the foal effects the growth and body development, as well as the age and growth stage of the horse.

2.3.2 Gender

Sexual dimorphism is reported both for growing and adult horses. At the adult age, stallions are on average 10% heavier than mares. In growing horses, whatever the breed, males are heavier and have bigger body measurements than females, the differences increasing with age.

2.3.3 Nutrition

Nutrition plays a major role among the environmental factors that influence foals' growth and development (see Chap. 3). Also, the birthweight correlates with the BCS of the dam, obese mares having heavier foals. In suckling foals, the growth performance appears to be influenced by mares' BCS changes due to their feeding status during the first 3 months of lactation, with lower growth rates observed in foals whose dams presented negative BCS changes throughout this period. Later, foal's body weight and body size increase with feed intake level and are influenced by the foal's diet, namely by the type and quality of forage or concentrate composition. Foals' digestive capacity is also linked with gut development (see Sect. 2.6).

The birth date effects on the foal's growth and development during its first year of life. This is closely related to mare's and after weaning foal's nutritional status and feeding management (e.g., pasture availability, feed quality). For example, Thoroughbred foals born in the USA in January and February have been observed to have lower BW than foals born in March, April, and May during the first 3 months of age, but these differences disappear at 5 months of age, which can be explained by an increase in the ADG of the lighter foals coinciding with spring pasture growth in April. In northern latitudes, the most beneficial birth month for the foal's development is May, when the horses can benefit from the grazing (high-quality grass, increased free exercise) both during their first and yearling years. Respectively, in many studies, the slowest growth has been reported to be in foals born in late summer and thereafter because of poor availability of pastures and soon after foaling beginning of indoor feeding period. Further, in cold environments, young horses need additional energy for maintenance, and this energy is not available for growth, resulting in slower growth rates (see Chap. 3).

Development can occur even if growth slows down due to an inadequate nutrition. Compensatory growth usually happens when growth is restricted under the genetic potential. If growth is reduced by restricted energy intake, this may result in compensatory growth at later stage. Compensation of reduced growth during winter feeding season will occur on pasture, when herbage production and quality increases, and horses can move freely. However, the ability to undergo compensatory growth will decrease with age (see Chap. 3).

2.3.4 Exercise

Free or organized (breaking, training) exercise promotes the growth and bone formation of young horses. The positive effect of exercise and early training on bone health and strength as well as muscles has been reported in many studies in racing breeds (see Chap. 6). Breaking and training should begin while the horse is still growing, when the horse's body (bones, muscles) is sensitive to training effects. For example, Thoroughbreds horses reach 94–98% of their final HW already at the age of 2 years (Fig. 2.2a). Thus, the increase in their bone length practically ends at the age of 2 years, but the load, or exercise, causes bone growth and development as bone activity increases, and the horse's size still increases slightly (the remaining percentage of adult size). Starting the training and competition career at a young age has been shown to be beneficial for horse development and competitive success, too.

2.4 Modelling Growth and Development

Growth patterns have been described using linear regression models, including the quadratic effect of time. However, for longer periods and for larger volume of data, models which are nonlinear in their parameters adjust better to data and, usually, have an easier biological interpretation. The most accurate sigmoid model that has been successfully used to study BW and HW growth in Thoroughbreds and other sport horses was the Richards function.

Although horse breeds, e.g., heavy cold-blooded, warm-blooded, and thoroughbreds, differ in type and size, their growth could be quite similar in their general shape (Fig. 2.2). However, due to environmental influences, differences in the patterns of growth can be observed, also within the same breed. Growth dynamics and mechanisms have been studied and reported for some horse breeds (e.g., Thoroughbreds, Standardbred, cold-blooded trotters, warmblood, Selle français, and the Lusitano). Thoroughbreds mature more rapidly than cold-blooded horses (e.g., Finnhorse and Swedish and Norwegian trotters) which are considered slowly developing breeds. Standardbred trotters achieve their adult size and maturity about 1 year later than Thoroughbreds. Consequently, the maturing is not really finished when trainers put the horses under a rider or in front of the sulky and start to train them. In spite of that, in different breeds, including the so-called slow-growing ones (for example cold-blooded horses, Icelandic horse), the closure of growth plates occurs at approximately the same age, with an average age of 25–31 months. This between-breed similar pattern concerning skeletal development supports the observations of comparable growth rates in HW among different type of horses (Fig 2.2a).

There is a negative relationship between developmental rate (adulthood rate) and adult weight, i.e., large animals are slow-growing and -developing. Thus, the selection of large animals at different stages of growth increases the size of the animals but not their rate of development. In addition, individuals of big (adult) size are growing and developing slower than their smaller contemporaries.

Studies show that the individual conformation of the horse has been found to take shape at an early age. Three intensive stages in horse growth can be distinguished: the first months of life (4–6 months), from weaning to about 1 year of age (10–12 months), and growth after puberty (up to 2 years of age). Although with a great variability, horse reached the puberty at 10–12 months of age (males being less precocious than females). However, the onset of puberty varies with breed, season of birth, photoperiod, and nutrition.

Key Points

- The growth rate is influenced by age and delays smoothly when the foals become older.
- At birth, foals from light breeds average 10% of their adult BW and 60% of their final withers height (HW). At 6 months of age, the foal has achieved approximately 85% of its HW and 45% of BW. After this age and depending on the breed and management conditions, ADG progressively decline until maturity. At the age of 18 months, Thoroughbreds, Standardbreds, and coldblooded trotters have achieved approximately 95% and 75–80% of their mature HW and BW, respectively.
- The growth and development are influenced by heredity, gender, nutrition, and exercise.
- There are quite high positive correlations between the growth rate of the first year of life and the adult size. The preference for large size in certain selection programs may lead to rapid growth in the first year of the foal's life, and vice versa.
- In growing horses, whatever the breed, males are heavier and have bigger body measurements than females, the differences increasing with age.
- Nutrition plays a major role among the environmental factors that influence growth and development. Compensatory growth usually happens when growth is restricted under the genetic potential. If growth is reduced by restricted energy intake, this may result in compensatory growth at later stage.
- In suckling foals, the growth performance appears to be influenced by mares' BCS changes due to their feeding status during the first 3 months of lactation, with lower growth rates observed in foals whose dams presented negative BCS changes.
- Regular exercise promotes the growth and bone formation of young horses. The positive effect of exercise and early training on bone health and strength as well as muscles has been reported in many studies in racing breeds (see also Chap. 6).
- Growth patterns have been described by several models, including the quadratic effect of time. However, nonlinear models adjust better to data and may have an easier biological interpretation. The most accurate sigmoid model that has been successfully used to study BW and HW growth sport horses is the Richards function.
- Foals that grow very fast are at increased risk of DOD. Moderate growth rates may be preferred to minimize bone abnormalities in young horses. Although horse breeds differ in type and size, their growth could be quite similar in their general shape.
- It is unlikely that an absolutely smooth growth curve can be achieved because of many genetic and environmental factors affecting the growth and development.

2.5 Gut Development

Accompanying visible external changes of growth and development, the foal intestinal tract will undergo both anatomical and physiological modifications.

2.5.1 Anatomical Changes

From 1 to 4 weeks of age, which corresponds to the period of the most rapid growth of the foal, the increase in total intestinal and small intestinal length is the greatest. The highest lengthening of the small intestine may increase the mucosal surface area for lactose digestion and absorption of galactose and glucose in response to the increased milk consumption during this period. Later, the relatively large decrease in small intestinal length corresponds to a great increase in the large intestine (caecum, ascending ventral and dorsal colon, and descending small colon) between one and 6 months of age. These modifications occur in parallel with the increase in time spent foraging, which rises the amount of forage consumed, therefore enhancing the ingestion of structural carbohydrates. The development of the caecum and colon probably provides larger fermentation compartments necessary for the microbial digestion of the structural carbohydrates. However, the ventral colon has few haustra in the suckling foal contrary to the weaned animal. Since the digestion of milk is presumably completed in the stomach and small intestine, the suckling foal has little need of large fermentation compartments. On the contrary, in the weaned foal, well-marked and characteristic haustra are seen in the ventral colon and in the dorsal colon even if fewer than the ventral colon. This may be evidence of the functional activity of those fermentation compartments as the weaned foal ingests a larger amount of structural carbohydrate.

The specific factors initiating the change in function of the different parts have not been defined. It seems reasonable to assume that pituitary, adrenal, thyroid, and gastrointestinal hormones play some role in gastrointestinal differentiation in horses, similar to the situation in other species.

2.5.2 Transit Changes

In the suckling foal, the stomach contents appear predominantly liquid. The gastric emptying is delayed compared with the weaned foal. Similarly, the small intestinal transit time is slower while the ventral colon empties more quickly than that of the weaned foal. In the weaned foal, the transit of feeds is quicker through the stomach and small intestine and feeds were shown to reach the caecum and right ventral colon within two hours after feeding. In the ventral colon, the transit of feeds is slow from the right to the left ventral colon. This probably allows the digesta to be subjected to a thorough mixing.

Interestingly, the overall time for intestinal passage of a meal before and after weaning was reported to be very similar to the time required in adult horses. It can be concluded that there must be a significant increase in rate of ingesta flow during life in horses to match increases in intestinal length (Table 2.2).

Table 2.2 Proportions (mean percentage) of small intestine, caecum, ascending colon and descending colon, and total intestinal length (m) observed in horses during development (adapted from Smyth 1988)

Age class (days)	Small intestine (%)	Caecum (%)	Ascending colon (%)	Descending colon (%)	Total intestine length (m)
150–329	76.1	2.8	10.6	10.5	5.7
330–346	81.1	2.0	9.1	7.8	11.1
347–505	80.3	2.5	9.9	7.2	14.1
+ 506	73.6	3.5	12.5	10.3	21.8

2.5.3 Enzymatic Changes

Significant differences occur in the foal stomach with postnatal age. In the new-born foal aged 1 day, plasma concentrations of gastrin are low, which limits the secretion of hydrochloric acid in the stomach and is propitious for the protection and absorption of immunoglobulins in the small intestine. Plasma gastrin after feeding rises in foals aged 2–7 days and may be caused by increased feed intake. This gastrin increase induces changes in gastric pH that is high in acidity in newborn foals and decreases from the second day and within the first 3 months of life. This may prevent protein degradation by pepsinogen, as pepsinogen is active optimally in the pH range 1.8–3.0.

Two enzymes with lactose hydrolyzing activity have been measured in the small intestine of the foal: neutral beta-galactosidase, which has the highest activity, and acid beta-galactosidase. The maximal level of both beta-galactosidases is reached at the foal birth. By 15 weeks of age, the high birth level decreases to the range of activity recorded subsequently along the small intestine throughout the horse's life. The pattern of lactase development reflects the capability of the foal to utilize lactose, the principal source of energy at birth and in the immediate perinatal period. Other enzymes with disaccharide hydrolyzing activity have been detected in the small intestine of the foal: maltase, sucrose, trehalase, and glucoamylase all classified as alpha-glucosidases. Their activity is low at birth, there is a steady increase during the suckling period to reach adult levels after weaning. This pattern of development indicates the increasing capability of the young animal to digest other carbohydrates through the suckling period to become fully competent at, or around, the time of weaning.

The enzymatic digestion of carbohydrates is unlikely to be of any importance in the large intestine. In this part of the gastrointestinal tract, microbial digestion will occur.

2.6 Gut Microbiota Establishment and Nutrient Digestion

The microbial colonization of the foal gastrointestinal tract is a crucial stage in the life of an individual because it shapes the microbiota structure and function of the young, future adult.

2.6.1 The Sequential Process of Microbial Colonization

The microfauna composed of ciliated protozoa colonizes the large intestine in small quantities from the 11th or 12th day of life. Microscopic observations suggest that the fungal microflora would also be implanted before the second week of life. Bacteria colonization is better documented and shows that the most important changes in the foal fecal bacteria occur between birth and the second day of life. The number of total anaerobic bacteria increases sharply as well as the bacterial biodiversity. Some species of pioneer bacteria are transient such as *Escherichia* and *Bacteroides* whose abundance drops drastically later. Other pioneer genera establish definitively, such as enterococci, enterobacteria, lactobacilli, streptococci, staphylococci, and clostridia, which have been counted in the feces of 24-hour-old foals.

The bacteria that colonize the gastrointestinal tract of the young foal are of maternal and environmental origin. As the foal does not consume its mother's feces in the first 24 h of life, coprophagy would not be essential for the establishment of bacteria in the gastrointestinal tract of the foal in the first days of life. The great similarity between the bacterial species (OTUs) present in the mother's milk and in the feces of the foal at 48 h and at 1 week of life suggests a very strong imprint of the milk diet in the colonization of the large intestine during the foal's first days of life.

Within the first 24 h of life, bacteria have the capacity to hydrolyze starch and lactate. Amylolytic bacteria identified in the young foal's feces belong to the genera *Bacillus* and *Lactococcus* that can hydrolyze lactose, galactose, and glucose from milk in the large intestine to produce lactic acid. Lactic acid is then degraded by lactate-using bacteria, resulting in the production of short-chain fatty acids whose fecal concentration at 48 h of life was twice higher in foals than in their mother.

Between 4 and 6 weeks after birth, the populations of bacteria and fecal protozoa of the foal increase and diversify very rapidly to reach maturity and resemble those of maternal feces. These changes in the structure of microbial populations accompany the establishment of new digestive capabilities such as the degradation of cellulose and hemicelluloses. This results from the evolution of the foal's diet.

2.6.2 Implementation of Fibrolytic Function

Bacteria capable of degrading plant parietal fibers such as *Fibrobacter succinogenes* appear in the large intestine of the foal between the second and fourth day depending on the individual and their concentration increases significantly on the fifth day to reach an average of one hundred colonies per gram of feces. There is a correlation between cellulolytic bacteria, *F. succinogenes*, and the live weight of foals, which suggests the major role of fibrolytic bacteria in the digestion of parietal carbohydrates into essential nutrients for foal growth. In vitro studies reported that the fecal microflora of the foal has the capacity to degrade parietal carbohydrates equivalent to that measured in adults from 1 month of age.

Studies comparing digestibility in growing horses at various ages and in adult horses showed that digestibility values of younger horses are very similar to those observed in mature horses and that no big changes happen during the foal's growth. This suggests that weanlings can properly digest their forage-based diets.

Key Points

- From 1 to 4 weeks of age, the period of the most rapid growth of the foal, the increase in total intestinal and small intestinal length is the greatest. The highest lengthening of the small intestine may increase the mucosal surface area in response to the increased milk consumption during this period.
- Later, the relatively large decrease in small intestinal length corresponds to a great increase in the large intestine between 1 and 6 months of age, occurring with the increased consumption of forage, therefore enhancing the ingestion of structural carbohydrates.
- Enzymes with disaccharide hydrolyzing activity have been detected in the small intestine of the foal, having a low activity at birth, but a steady increase during the suckling period to reach adult levels after weaning.
- The microfauna composed of ciliated protozoa colonizes the large intestine in small quantities from the 11th or 12th day of life. The sharp increase in the number of total fecal anaerobic bacteria and bacterial biodiversity occurs between birth and the second day of life. The colonizing bacteria of the young foal are of maternal and environmental origin. Within the first 24 h of life, bacteria have the capacity to hydrolyze starch and lactate.
- Between 4 and 6 weeks after birth, the populations of bacteria and fecal protozoa increase and diversify very rapidly to reach maturity. These changes enable the degradation of cellulose and hemicelluloses. The foal can degrade carbohydrates equivalent to adults from 1 month of age, and the nutrient digestibility of younger horses is very similar to mature horses.

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Nutrition and Management at and after Weaning

3

Séverine Henry and Markku Saastamoinen

Abstract

Weaning is considered as one of the most stressful events in a domestic foal's life. Artificial weaning takes place generally several months prior to the "biological" age of weaning when foals are still in close relation with their dams. Particular attention should be paid to the foal's diet both before and after weaning because weaning is most often associated with weight loss of the foal. During the first 3 months of the foal's life, mare's milk covers the most part its nutritional requirements, and intake of solid feeds increases gradually when mare's milk production decreases. After weaning, regulated individual and balanced feeding is an important factor to prevent the risk for bone abnormalities. Foals fed ad libitum and excess energy have often a higher occurrence of conformational and musculoskeletal abnormalities than those fed with restricted diets. Weanlings are sensitive to protein level and quality, and young growing horses require high-quality protein responding. Increased growth in response to an increasing dietary protein level can only occur when essential amino acids are the limiting nutrients for growth. Mineral intake alone does not increase the bone density, but mineralization and bone formation happen only when young horses are exercised and loaded regularly.

Keywords

Weaning stress · Weaning practices · Balanced nutrition · Protein quality · Supplemental needs

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3.1 Introduction

Young horses go through key periods from the time of birth to early adulthood, including weaning. There is a large variety of horse breeders and breeding farms with different practices and compromises in terms of animal management and feeding and breeding practices. Weaning event is experienced differently between foals raised in socially natural groups and those raised in domestic environment. Without human interference, the weaning takes usually place around the age of 9–11 months and is strictly alimentary. Under domestic conditions, most foals are weaned artificially, at a relatively young age, and the breaking of the mare-foal bond associated with the cessation of suckling is often abrupt. Under such conditions, weaning is recognized as an important source of stress with immediate and long-lasting deleterious effects. After weaning, growth of the foals is regulated both by genetic and environmental factors. The genetic effects are reflected in differences between breed and individuals. This has to be kept in mind when assessing the nutrient requirements of the young horse. The growth and body development of foals is influenced more dominantly by energy and protein than other nutrients. In this chapter, recommendations for attenuating weaning stress and improving welfare of young domestic horses, as well as nutritional needs for healthy growth, are discussed.

3.2 Weaning and Feeding Practices: Foal's Behavior and Well-being (Séverine Henry)

3.2.1 Lessons from the Wild: A Point on the Development of Foals under Natural Conditions

Because horses have evolved for a long time without human interference (equine history began about 55 billion years ago, whereas horses were probably domesticated only 5500 years ago), it is essential to know the "normal" development of foals and young horses under naturalistic conditions in order to better understand why some husbandry practices may be inappropriate and lead to problematic issues.

Under (semi-) natural conditions, foals are raised within stable family groups usually composed of their mother, one family stallion (often their father), older siblings (up to 2–3 years of age), unrelated mares and their sexually immature offspring. Young horses thus develop within a rich social network which is essential to the behavioral development of foals and in particular to the acquisition of social skills. Social organization in horses living under natural conditions relies mainly on stable affinities between individuals (characterized by spatial proximity, each individual usually having 1 to 2, rarely 3 preferred spatial partners) and knowledge of the hierarchical status of all group members, thus reducing aggressiveness and social tensions.

Within their natal group, the first social bond foals form is with their dams, with first mother-young interactions taking place soon after birth. Foals are relatively mature from the moment of birth, being able within the first few hours to walk and follow their dams. During the first month of life, foals are largely dependent on their mothers as maternal milk represents their only source of nourishment: they suckle an average of 3–4 times per hour, which represents nearly 8% of their time budget and remain at close distances (within 5 m) from their dams more than 90% of the time. As foals mature and milk nutrient composition changes during the lactating period, mother's milk as a nutritional resource is gradually replaced by the ingestion and digestion of solid food. From the age of 2–3 weeks, foals begin to ingest solid foods and diversify their diet while continuing to suck maternal milk. Time spent grazing increases steadily: between 1 and 4 months of age, the time devoted to grazing in the daily time budget increases by 7 to 25%, reaching more than 40% by the age of 6 months, and 60% (which corresponds to the adult time-budget) by the age of 10 months. At the same time, the duration and frequency of suckling decrease with age, with a very clear drop between the first (8%) and second month of life (~3%). Time spent suckling varies very little thereafter: it still occurs one to two times per hour (~2%) until 7 months of age and then approximately once every two hours (~1%) until weaning. At this point, suckling is probably an important form of social interaction with the mother, as the percentage of total nutrients provided by maternal milk is then low. Transition from a milk diet to a solid diet is very progressive, allowing a gradual adaptation of the foal's digestive system (see Chap. 2) and is facilitated by the maternal model, as foals quickly mimic the grazing behavior of their dams. Mares encourage also their foal to orient toward solid foods by rejecting some of their suckling attempts usually as soon as they are 4–5 months old. Beyond the increasing dietary independency over time, foals as young as 3 weeks old start interacting with other group members, particularly same-age peers and older siblings and gradually spend less time within the close proximity from their dams even though their mothers will remain their preferred social partner for a long time.

Weaning in free-ranging situations is a progressive process resulting in a gradual reduction in milk intake combined with increased intake of solid food and increasing social independence from the mother. The final stage of the weaning process is though still quite unknown as few studies have been done at the later stages of the lactating period. Weaning occurs at variable ages, generally between 9 and 11 months, according mainly to the timing of arrival of the mother's next offspring when the mother generally prevents the foal from suckling. But it has been anecdotally reported that yearlings can still suckle their dams time to time in addition to their younger siblings or that, in the case of the death of the new foal, some mares continue to nurse their older young much longer. While the age at weaning does not seem to depend on the sex of the foal, several factors of variation have been identified, such as the present (i.e., pregnant/non-pregnant) or previous reproductive status (i.e., with/without yearling) of the mare, and in some cases her previous maternal experience (i.e., primiparous/multiparous). For example, mares that do not expect a new foal or did not have a foal in the previous year usually allow their offspring to suckle longer. Other factors such as the availability of food resources or the maternal body condition have also been reported.

In any case, "natural" spontaneous weaning only concerns nutrition with the mare-offspring social bond lasting much longer after the end of the suckling period.

Opportunities to interact with a variety of partners (i.e., siblings, peers, related and unrelated adult horses) continue to intensify at that stage and are assumed to be important in learning appropriate social behaviors, particularly inhibition of aggression. For instance, it was found in natural family groups of Przewalskii horses that the overall rate of aggression toward peers in 1-and-2-year-old horses was negatively correlated with adult-young ratio, meaning that adults inhibit agonistic interactions among young horses. The mother remains a preferential partner until juveniles leave at puberty their natal group around the age of 2 to 3 years. After dispersal, young mares join reproductive units while young stallions join a bachelor group.

3.2.2 Ontogeny under Domestic Conditions

3.2.2.1 A Quick Overview

What foals experience in the domestic situation is of course drastically different from the wild. Under domestic conditions, even if the mother-offspring bond is relatively preserved, some changes from the natural situation can be noted: among the most common, one can cite a less diversified social environment (e.g., absence of the father, siblings and older peers) and human interference around the mother-offspring bond which are often numerous especially at birth and during artificial weaning.

3.2.2.2 Artificial Weaning of Domestic Foals and its Consequences

Because of human convenience or tradition, weaning under domestic conditions differ from the natural process in several important ways. Artificial weaning, which is a common practice, is usually performed abruptly and accompanied by complete separation from the dam (meaning that foals are separated from their dams with no visual, olfactive or auditory contact and the pair will not be reunited). In addition, it generally takes place several months prior to the "biological" age of weaning when foals are still in close relation with their dams: most foals are weaned from their mother when they reach the age of 6–7 months, or even sometimes at 4 months age. Lastly, newly weaned foals often faced a wide variety of stressors in addition to the cessation of suckling and the breakdown of the mare-foal bond, which may include social disruption (e.g., social isolation, mixing with unfamiliar peers), physical environment changes (e.g., confinement, relocation, a new enclosure), dietary changes and increased human interventions.

Under such conditions, weaning is considered as one of the most stressful events in a domestic foal's life. It results in high levels of stress, with the expression of intense behavioral responses, including according to several studies long-distance whinny calls, active locomotion (trot, canter) and alertness postures, associated with elevated heart rate, increased glucocorticoid levels and a decline in body weight gain and growth rate. The well-known behavioral stress reactions mentioned above usually peak within the first 2 days following weaning prior to vanishing, suggesting, probably wrongly, that newly weaned foals adapt to the situation quite quickly. One has to consider that the rapid decline in general activity may rather be due to a state of tiredness or exhaustion following a particularly intense and lasting stressful situation. A few days after weaning, foals can be observed most of the time with half-closed eyes and low postures while walking slowly, but almost continuously. It is worth noting that cortisol levels have been found to remain elevated (compared to levels measured prior to weaning) until at least a month after the weaning day, while other behavioral changes, such as altered feeding and sleep patterns, suspension of play, high levels of aggression towards peers (if weaned in pairs or groups), but also expression of redirected sucking activities, wood-chewing, licking and chewing of fences or walls stemming from frustration, can also be observed for longer periods. Additionally, artificial weaning leads to chronic problems. Thus, hypercortisolemia leads not only to a decrease in the immune response and therefore to higher risk of infectious diseases, but also has a negative impact on the maturation of the intestinal microbiota, which can lead to the potential proliferation of harmful microorganisms such as *Escherichia coli*. Lastly, numerous scientific studies point out that early weaning is a major risk factor for the development of stereotypies due to the impossibility of expressing highly motivated behaviors. A study investigating the development of stereotypical behavior in young horses found that 34% of the 225 foals studied had developed in the following postweaning months some forms of abnormal repetitive behavior, which included crib-biting and box walking. The common practice of artificial weaning is therefore seriously detrimental to the well-being of foals.

While the impact of artificial weaning on foals has been widely examined, little is known about its effects on breeding mares. The few studies looking at the behavioral reactions of mares showed that artificial weaning is also a stressful time for them (characterized above all by alert postures, increased rate of neighing and increased locomotion). It is also assumed that most mares (especially those who have foaled in past years) calm down more quickly than their foal. But a recent work conversely highlighted that levels of cortisol remain high at least until a month following weaning. In addition, drying-off mares are also at risk to suffer from mastitis (i.e., infection and inflammation of the udder) up to 8 weeks postweaning, especially when weaning is performed during the summer. Additional investigations therefore seem necessary to better understand the consequences of artificial weaning on mares, especially since in most breeding farms mares are breeding each year and are therefore usually expecting a new foal at the time of weaning. One has to consider that artificial weaning, if perceived negatively by mares, may indirectly impact the unborn foal. There is in other mammalian species a growing body of evidence relative to the long-term negative consequences of maternal stress during pregnancy on the development (e.g., cognitive and socio-emotional development) of the unborn.

3.2.3 Strategies Used to Reduce Artificial Weaning Stress in Foals

Different approaches have been examined to reduce the negative effects associated with early artificial weaning in foals. Weaning method, type of feeding, social context, and physical environment in which weaning occurs have been studied as modulators of the intensity of stress responses in foals.

3.2.3.1 Preparing the Foal: Food Transition and Familiarization with its Surroundings

From a dietary point of view, weaning corresponds to the cessation of maternal milk consumption and the passage to solid, high fiber feeds, mainly grass and other forages. A way to limit the stress associated with artificial weaning is to prepare foals for this food transition in order not only to limit stress reactions at weaning, but also to avoid digestive problems which can disturb the correct growth and development of the foal. It is thus preferable to keep the same food that was fed to supplement (e.g., grass, hay, concentrates) dam's milk. Additionally, it is recommended to favor before weaning a diet rich in lipids and fibers rather than a diet high in soluble carbohydrates (starch, sugars), e.g., grains. Not only it attenuates weaning stress reactions, but also reduces the reactivity of weanlings when exposed to new people and unfamiliar objects. Similarly, keeping foals at grass prior and after artificial weaning can help foals better handle the stress of weaning, especially if kept in presence of calm adult horses who will prevent the typical decrease in time spent grazing in the post-weaning days or weeks. However, this is not possible in the northern latitudes where the foals are usually weaned in late autumn or early winter. Moreover, foals raised before weaning on pasture supplemented with hay and a pelleted concentrate providing phosphorus, zinc, copper and iron supplements neigh less eat more and have lower cortisol levels after weaning compared to foals raised on pasture supplemented with hay only.

Similarly, to decrease stress to the foals at the time of weaning, they should remain in the environment where they were raised and with at least the familiar same-age peers, to avoid any additional stress associated with novelty (relocation, loss of social partners other than their dam). Deworming, vaccination and castration should rather be delayed as well or done prior to artificial weaning if possible.

3.2.3.2 Weaning Methods: Is there a Better Way to Artificially Weaned Foals?

There are a variety of weaning methods used in the horse industry, but the most widely used today is the forced, abrupt and complete physical separation of foal and mare. As an alternative to this traditional abrupt method, progressive weaning has been suggested with the assumption that mares and foals could get progressively habituated to be separated before permanent separation. It consists of either short episodes (10 min) of total separation from the mother repeated before definitive separation, or a gradual increase in the time (from 15 min to 6 h during the last week before weaning) of partial (with visual, auditory and olfactory contact), then total separation from the mother over a period of several weeks prior to weaning. However, it is difficult to draw a definitive conclusion on the effects of progressive weaning based on only a few studies.

On the one hand, repeated separations from the mother prior to weaning appear to sensitize foals to the stress of permanent maternal separation, resulting, as compared to foals abruptly weaned, in greater stress responses the day after weaning when the duration of maternal separation becomes longer than usual. On the other hand, progressive weaning seems to have some benefits (i.e., lower rate of whinnies and locomotor activity on the day of weaning, lower cortisol levels on the day after weaning), but unfortunately no behavioral data have been collected in studies on the day after weaning (when the duration of maternal separation exceed 6 h and becomes unusual) to confirm the beneficial effects in foals. Further, progressive weaning seems to be ineffective in preventing both a significant decrease in average daily weight gain in the first post-weaning week and elevated cortisol levels over the first post-weaning month. Lastly, repeated separations of mares and foals before weaning, if stressful, could inhibit the proliferation of bacterial species adapted to a cereal-based diet due to the sustained release of stress hormones.

Fence line weaning is another gradual method, where dams and their foals are at first separated by a fence allowing auditory, visual and nose-to-nose contact. Study results indicate that foals weaned this way exhibit fewer signs of stress than those weaned by abrupt separation, but information is missing on reactions of foals when mares are moved completely away, as well as on the risk of mastitis in mares (the decrease in milk production may be delayed as they are still in partial contact with their foals).

Lastly, a recent study investigated the effect of a two-stage weaning method in which foals are prevented for several days from suckling with the use of an udder cover on the mare (nutritional separation) before being separated from their mother in a manner similar to the abrupt method (physical separation). During the first stage, no significant behavioral and physiological changes were scored in foals, but, as soon as mares were removed, classical signs of stress were exhibited.

Taken all together, the alternative methods to the traditional abrupt method appear, at least for some of them, to have limited benefits, and even sometimes can lead to effects opposite to those desired. This may be due to the fact that such methods, like abrupt weaning, do not mimic the natural temporal dynamics of the dam-foal bond and therefore can be as stressful as an abrupt maternal separation. Termination of physical contact between the dam and its foal is not a normal component of weaning in horses, which may explain why the main stressor associated with artificial weaning is not the cessation of milk intake, but the permanent separation from the mother.

3.2.3.3 Weaning Recommendations Concerning Social Context at Weaning

The social context has a strong influence on the stress reactions of newly weaned foals, which is not surprising since they experience social distress at the time of weaning. The highest short-term stress reactions are observed for foals weaned alone in stall boxes, not to mention that confinement is also well known to favor the expression of aberrant behaviors ranging from occasionally pawing to frequently licking stall walls, and the development of stereotypic behaviors. When paired in a box with a peer, foals often exhibit less signs of stress (e.g., decreased rate of whinnies) and are less at risk to develop abnormal behaviors, but aggressions do arise and can lead to injuries or even additional stress. It is therefore important to consider social preferences when pairing to increase social tolerance, as well as to provide enough space to allow some social distancing, otherwise weaning in pairs may be more stressful than weaning alone. Weaning in a group in a paddock results in lower indicators of stress and facilitates a more rapid return to normal activity than social isolation in box stalls, even though, as in foals weaned in pairs, redirected sucking behaviors toward herd mates inevitably emerge. While the presence of same-age peers clearly helps to better cope with artificial weaning, other practices, such as the progressive retrieval of mares from the group or the introduction of adult horses with the weanlings, lead to even lowered expressions of stress, suggesting that the presence of adult models, either familiar or not, plays a key role.

Above all, introducing socially experienced adults in groups of weanlings appears as the most promising approach to date: in comparison to weaning with only same-age peers, it allows weanlings to adjust to maternal separation more easily, prevents the typical decrease in time spent feeding following weaning and is associated with reduced aggressiveness, better social cohesion, as well as lower levels of abnormal behaviors (e.g., wood-chewing, licking/chewing of various substrates) or even redirected sucking behaviors. In horses, as in other species, the presence of calm adults can lower arousal during exposure to stressful events, promote a normal temporal distribution of main via social facilitation and favor better social competencies in juveniles. Beyond positive effects on reactions to weaning, it is worth noting that keeping weanlings with adults is the only artificial weaning method which promotes better social development in juveniles.

Key Notes

- Weaning in natural free-ranging situations is a progressive process resulting in a gradual reduction in milk intake combined with increased intake of solid food and increasing social independence from the mother.
- Artificial weaning generally takes place several months prior to the "biological" age of weaning when foals are still in close relation with their dams. Under such conditions, weaning is considered as one of the most stressful events in a domestic foal's life.
- It is often considered that a foal can be artificially weaned from the age of 4 months because its nutritional needs then exceed the level of nutrients available from maternal milk, but, if we consider rupture of the mare-foal social bond, it is far too early. Thus, it is relevant to pay attention to individual variations in the strength of the social bond between dams and their foal rather than on the age of foals.

- Foals closer to their mother experience more stress at weaning, for a longer period, and need more time to fully recover.
- As long as the dam is in good health and can maintain an acceptable weight or body condition, artificial weaning should be delayed (if the breeding constraints allow it) to allow continued social development.
- The highest short-term stress reactions are observed for foals weaned alone in stall boxes.
- Particular attention should be paid to diet, because artificial weaning is most often associated with weight loss. One solution is to provide before weaning foals a mixed diet including plenty of forage combined, if needed, with low amount of concentrates to facilitate the transition to a solid diet. A rapid switch to concentrates can induce the development of stereotypic behaviors and gastric disorders.
- Space, dispersed resources and social diversity (i.e., presence of same-age peers and adult conspecifics) may help foals go through this artificial separation from the dam without developing aberrant behaviors and higher level of aggressiveness.
- The mare's individual characteristics (e.g., whether primiparous or multiparous; whether pregnant or not; if pregnant, her stage of gestation) should also be considered when choosing the best time to perform artificial weaning. Spontaneous weaning induces absolutely no stress response in either partner (nor a decrease in body condition in mares) and is a step to go toward a more "welfare-friendly" breeding management.

3.3 Nutrient Requirements of Weanling Foals (Markku Saastamoinen)

Adequate quantities of mare's milk cover the most part of the nutritional requirement of foals during the first 3 months of life. Foals begin to ingest small amounts of dry feed (grass, other well-digested forages) usually during the first 10 to 21 days of life but can taste pasture grass even at younger age, learning it by imitating the dam. Although the feed dry matter and nutrient intakes are increasing as the foals mature and increase their body size, the proportion of solid feeds increases slowly with decreasing dam's milk production until weaning. During the sucking period, high-quality pasture feed other than milk is not required to cover the energy and protein needs of the foal. Between 1 and 4 months of age, the time devoted to grazing in the daily time budget increases by 7 to 25%, reaching more than 40% by the age of 6 months. Mare's milk production and growth rate of the sucking foal decline between months 4 and 6. Same time the lactase activity decreases and that of sucrose and maltase increases enabling the digestion of non-structural carbohydrates in plant-based diets.

Nutritional needs and feeding management are crucial regarding bone health and development. Nutrition during the first 2 years has a greater impact on the growth than in older horses because the growth speed is flattening at this age. Thus, proper nutrition of weanlings and yearlings to ensure their normal and healthy growth and development sets great demands on breeders. Introducing the foal to the solid feeds to be fed after weaning may be beneficial before weaning helping foals to start ingesting the feeds at a proper amount and contributes adaptation of microflora to new feeds. However, just providing good nutrition will not optimize bone health if the correct exercise is not being afforded to horses, as discussed in Chap. 6.

Feeding of growing horses is based on good-quality forages. The efficiency of microbial digestion could be limited if lower quality forage-rich diets are applied. When a new feeding is starting and new feeds are introduced, it is important to do it slowly (starting 3 to 4 weeks prior to weaning) and gradually and increase the amount of concentrate as necessary. Diet rich in fiber and fat may enhance adaptation to post-weaning diet (see also Sect. 3.2.3.1 and Chap. 5).

3.3.1 Energy Requirements

The foal uses energy for growth and maintenance. When the growth is slowing down with its age, the proportion of energy used for growth decreases and that for maintenance increases. After the age of 18 months, young horses are estimated to have maintenance requirements similar to mature horses.

Foal's growth is usually monitored by body weight (BW) and withers height (HW) gains (see Chap. 2). Body weight gain reflects generally the growth of all tissues, when growth of height at withers is a measure of skeletal growth. However, weight gain is stimulated to greater extent by the energy intake than skeletal growth. Higher level of energy supply results mainly in an increase of BW, whereas HW does not increase to a comparable extent. Further, studies show that young horses fed for rapid growth may not maximize bone deposition. If growth is reduced by restricted energy intake, this may result in compensatory growth later. For example, compensation of reduced growth during winter feeding season will occur on pasture, where good feed is available, and horses can move freely.

The level of energy intake may influence skeletal development and the incidence of developmental problems. Studies show that ad libitum and excess energy fed foals have often a higher occurrence of conformational and musculoskeletal abnormalities than those fed restricted diets.

It has to keep in mind that it is the energy intake which plays the role and that the forage component (hay, haylage, pasture) of the diet forms usually the main part of the feed portion, varying from 50 to 100%. Consequently, the nutritional quality and nutrient intake (including energy) from forages have a greater impact on the amount and quality of nutrients consumed than the concentrate portion of the diet.

Higher concentrate intake causes lower intake of forage and vice versa. The accelerated growth causing skeletal abnormalities has been found to be related especially with high intakes of easily digestible carbohydrates (sugars, starch) containing concentrates, which causes hormonal changes stimulating a rapid growth of cartilage resulting in its improper maturation. Studies show that foals with unlimited access to high-energy creep feed may exhibit signs of developmental orthopedic disease (DOD) which usually occurs during the most intense postnatal growth phase and growth spurts. Consequently, if extra feeding or creep-feeding is used, it is important to formulate the feed and diet individually for growth requirements and evaluate and balance all nutrients relative to the energy intake (see Chap. 6). In addition, some studies suggest that replacing diets rich in starch and sugar with fat and fiber-rich diets may be beneficial to mitigate risks of osteochondrosis (OC), but some studies show no difference, because, for example, also rate of consumption, diet composition (nutritional balance) and activity level are affected. Clinical data is lacking, and further, some research suggested that Ca and other mineral needs are increased when consuming diets with high fat and fiber (see Minerals).

Avoiding excess energy especially to foals that may be genetically predisposed to bone abnormalities may benefit from diets of lower energy density. Regulated individual and balanced feeding—i.e., avoiding both over- and undernutrition in any diet—is an important factor to prevent the risk for bone abnormalities.

After weaning, the appetite and feed ingesting of the foal may decrease due to the weaning stress and new feeds declining the energy intake. This can affect the growth curve of the foal; first slowing down and then speeding up the growth. This fluctuations, especially rapid growth rate and growth spurts, have been suggested to be related to the increased risk of development of DOD. Thus, these fluctuations have to be tried to be avoided to reduce the risk of DOD, although it is unlikely that an absolutely smooth growth curve can be achieved because nutrition is only one factor affecting the growth pattern (see Chap. 2). However, the correct dietary conditioning of foals prior to weaning is essential. If creep-feeding is applied in purpose to smoothen the growth curve after weaning, feed intake has to be regulated individually, as stated above.

According to studies, 54–57 MJ ME/62–65 MJ DE/d for weanlings (from 6–7 to 12 months of age) and 57–69 MJ ME/66–79 MJ DE/d for yearlings can be recommended for normal and optimal growth. As said, the feeding level has to be adjusted individually, based on the sex, breed, ambient weather conditions (see below) and genetic (= individual differences) of the horse (estimated based on the size and orthopedic health of the parents). Foals and yearlings with skeletal abnormalities or at risk should not be overweight. Excess energy, especially during periods of slow growth and when the proportion needed for growth has decreased with age, results in overweight when energy is stored as fat.

Adjusting the energy level of the diet effects rather the body weight than height (skeletal) growth of the young horse, because the heritability of, for example, withers height is very high, even over 90%. Growth on the bone length continues after decreased energy and protein intakes. When energy intake is regulated, both concentrate and forage intake must be controlled, and the diet be adjusted to meet the needs of other essential nutrients for growth and development. For example, to maintain skeletal quality, the protein intake must be proportional to energy intake. It is also important that mineral intake matches with energy intake, which may not be the case when energy is oversupplied.

Excess weight on bones and joints of a growing horse is more detrimental than being underweight. Monitoring the BCS (based, e.g., so-called Henneke system) of the growing horse is a good tool for the assessment of overweight in foals and can be used when energy intake is regulated to control BW. Horses with overweight and a BCS of 7 or greater may be at greater risk for developing DOD. Often the unsoundness caused by DOD may not become apparent before a young horse enters into training or competition. Low BCS shows undernutrition and may alter the foal to developmental disturbances due to lack of many nutrients. For these purposes, the BCS has to be checked every 21 days.

Why Various Energy Systems

For energy nutrition, there are various energy systems and recommendations applied in different countries. The recommendations may also apply different age intervals for growing horses, which makes it difficult to compare them. However, the practical recommendations are fairly similar. In any case, the recommendations are always compromises.

In each case, it is relevant to apply recommendations which take into account the typical geographical and national circumstances. These are for example climate, vegetation and feeds, as well as breeds and uses of horses. One important varying factor is the forage quality, which effects the daily forage intake. The German recommendations consider the type of the horse, and for example give lower recommendations for ponies and cold-blooded horses compared to warm-blooded or thoroughbreds. Instead, NRC considers various growth intensities.

Recommendations depend on the composition of the typical diets, targeted growth rate, quality of the protein in the feeds, feed intake capacity, activity and other individual effects of the horse. In some recommendations minimum requirements are considered, when some may give “optimum” recommendations.

Digestibility is the major factor determining the energy value of feeds. Because of different traditions the energy units vary between countries. The most common units used in animal nutrition in different countries are Digestible Energy (DE) and Metabolizable Energy (ME). Feed energy potentially utilizable by the animal is the ME.

Because part of the total energy is lost through urine end intestinal gases, ME provides a more accurate measure of a feed’s energy value than DE. ME is calculated from DE subtracting the energy lost in through urine and intestinal gases. In ME the energy value of feedstuffs is depending on the chemical composition of diets. The proportion of ME in DE (ME/DE) depends primarily on the type and characteristics of feeds: 78–80% for oil plant seed meals, 84–88 for forages, 91 for straws and 90–95% for cereal grains.

ME presents the portion of the energy which is available for the body’s many functions, and the ME requirements can easily be defined for any condition. ME provides a more accurate measure of a feed's energy value for the animal than DE. Using ME for horses is justified because it is used for most species associated with a valid structure for feed evaluation. For growing horses and lactating mares with large protein intakes, their importance increases.

In some recommendations (e.g., INRA, France), Net Energy (NE, expressed in horse feed units, UFC) is applied. It represents the proportion of the energy that can be used by the horse for growth, production of fetus and milk, work and maintenance of the body.

In many European energy systems, energy requirements are depressed in joules (usually megajoules MJ). Instead of that, in the USA (NRC), requirements are depressed in terms of kilocalories (kcal) or megacalories (Mcal). The *energy in joules is equal to the calories multiplied by 4.184*.

3.3.1.1 Effect of Cold Weather

Maintenance energy requirement may elevate due to cold environment, being higher in cold-housed than in warm-housed foals and young growing horses. The thermoneutral zone has been defined as between 0–5 °C and 20–25 °C in horses. When horses are kept in cold or harsh weather below the lower critical temperature (LCT), additional demands for heat production should be considered to avoid weight loss. The average LCT of the thermoneutral zone depends on the breed, type and age of the horse. The LCT is higher for pony compared to light Thoroughbred type foals, because pony foals have a lower resting metabolic rate and, therefore, tolerate worse cold than light horse breeds. There is also variation in coat development, and thus, in cold resistance, some ponies and cold-blooded horses being most suitable for loose housing. For the suckling foal, the average LCT is higher than for older foals, approximately +20 °C. Metabolic rate rises as the ambient temperature declines below the LCT. Additional energy is then needed for maintenance, when energy used for this is not available for growth.

Horses have thermoregulation capacity and some ability to adapt to cold climatic conditions. They increase their metabolic rate in cold which ability is influenced by the body insulation, i.e., thickness of subcutaneous fat and their coat. The body fat provides energy if the foal is nourished properly. Further, climatic energy demand gradually decreased as the horses acclimatized to the cold housing environment. In addition, the decreased growth during aging of the foal and young horse decreases the energy expenditure for growth. Over 2-year-old young horses have more fat because the percentage of fat of the weight gain is larger than in younger horses. Same time the ambient temperature is increasing from winter to spring, causing decline in the need of energy to heat production. These reductions in the energy requirements are necessary to be taken into account to avoid fattening of the growing horses.

Studies report moderate heritability estimates for body condition score (BCS), i.e., accumulation of fat under skin, which means a clear hereditary background causing individual differences of this character. In addition, growing males tended to be leaner and lighter than females, who accumulate more body fat compared to males. Consequently, all these factors are affecting cold resistance of an individual horse and should be considered. It is important to monitor the BCS regularly, e.g., every 21–30 days. Foals appear to have little or no brown adipose tissue (fat) which in many other species can generate heat via uncoupling protein in brown fat.

Studies show that daily temperature fluctuations under cold conditions have very little effect on weight-scale energy intake for growth by properly fed horses. Activity level of the horses also affects the metabolic rate and energy consumption. Horses may lose weight stabled outdoors if extra feed is not available, which can be used to decrease the BCS. Also managing horses in a year-around grazing system using forest pastures with low energy value vegetation may be suitable for obese horses.

In some cases, the horses can spare energy for heat production by decreasing the amount of voluntary exercise, when, in fact, their energy intake may decrease. Energy requirements for exercise are unlikely to be affected in low temperatures.

The recommendations in the literature for extra energy due to cold weather are only indicative. The extra energy needs depend on the ambient temperature and management system (type of shelter, e.g., isolated, non-isolated, etc.) and age and weight gain of the horse as well as on group dynamics. Also, precipitation and wind must be considered in defining the energy levels of growing horses kept in outdoor stabling systems in cold environments. If warm shelters are used or horses are blanketed, the need of extra energy for heat production decreases. Energy requirements for exercise are unlikely to be affected by low temperatures. Feeding high-quality forage with extra amounts is a proper way to supply additional energy in cold weather.

3.3.2 Protein and Amino Acid Requirements

Protein is the major component of all tissues in the animal's body, and foals need protein for body growth. The protein requirements of foals are higher than those of other horse categories and depend on their growth rate and growth potential. To evaluate the protein requirements for growth, knowing these and actual body weight is essential. Also, the maintenance requirements in growing horses are higher than in adult horses.

Mare's milk is the primary nutrient source of foals, and it provides the foal all the needs during the first months of life, until the foal starts to eat solid feeds in increasing amounts until weaning. When the foal is aging and its growth rate is slowing, the protein content of the gain is decreasing.

As the digestive system of the horse is developed by the age of about 1 year, also young horses are capable to utilize dietary protein well. Thus, residual and endogenous nitrogen reaching the caecum can be modified by microbial synthesis.

Microbes of the lower digestive tract may then improve the biological value of lower quality protein, but only a small proportion of the amino acids (AAs) present in microbial protein is made available for utilization and can be absorbed from the large intestine. Crude protein (CP) digestibility depends on dietary factors, e.g., amount, source and composition of fiber, as well as protein source and amount: CP digestibility is improving with increasing CP intake but decreasing with increasing fiber content. It is recommended in growing horses that forage with a high fiber content should be avoided in the diets of horses under 1 year of age.

Several studies show that weanlings are sensitive to protein level and quality, and young growing horses require high-quality protein responding to indispensable amino acid supplementation with improved growth. Protein requirement of horses is smaller when they are given good-quality protein. Inclusion of the first-limiting amino acids in the diet may improve amino acid balance and through it also amino acid utilization. Cereals and roughage which are usually fed to horses are deficient in several essential amino acids including lysine, threonine and tryptophan. These critical amino acids are also the least digestible AAs, particularly in cereals. Imbalanced mixtures of AAs further decrease the utilization of limiting AAs and reduce food intake and growth.

Dietary CP contents ranging between 12 and 16% are recommended for weanling foals and yearlings. According to studies, 13–17% of CP can be recommended to foals which are weaned earlier (at 4 months of age) than between 4 and 6 months of age. The requirement decreases after the age of 9–10 months, and studies show that weanlings do not benefit from protein supplementation after 8–10 months of age. Low-protein diets (>9% CP) may depress bone turnover compared to the recommended CP levels.

The digestible CP (DCP) recommended in many feeding standards vary approximately between 450 and 500 g DCP for weanlings (6–7–8-12 months, mature weight 500 kg), and 400–450 for yearlings, assuming that lysine intake is as recommended. The energy-to-protein ratio can be recommended to be about 1.13 and 0.16 MJ DE/g DCP for weanlings and yearlings, respectively. Pre-cecally absorbable protein is used in German and French systems and is considered a more direct criterion compared to total tract digestible CP.

Increased growth in response to an increasing dietary protein level can only occur when essential AAs are the limiting nutrients for growth, i.e., improved protein quality can allow lower CP intake. When the protein quality (amino acid composition) is poor, excess dietary protein may reduce the growth, because it may cause additional energy costs due to extra heat production due to the catabolism of the excess amino acids. Further, excess dietary protein (116% of NRC) increases fecal Ca excretion and decreases Ca absorption.

3.3.2.1 Amino Acids

The list of limiting amino acids (AAs) is different for different animal species. In weanling and yearling horses, lysine and threonine have been reported to be growth-limiting AAs, and arginine in nurslings. AAs used for protein synthesis are taken up from blood after feed ingestion. They can also be generated from the breakdown of muscle protein. The availability of AAs (high-quality dietary protein intake) promotes protein synthesis and inhibits protein breakdown. The release of AAs from skeletal muscle reflects the catabolism of muscle protein and the synthesis of some AAs in this tissue. In addition, it is only the intake of individual AA but also AA balance that plays a role in foal's growth.

Lysine is an intensively investigated AA in horses, and the detrimental effect of its inadequate supply on growth is well documented in the literature. Studies show that lysine supplementation improves the growth of weanlings, and weanlings are most sensitive to protein quality before the age of 8–10 months, responding to lysine supplementation, which is in accordance with their growth pattern.

Based on wide literature, NRC (2007) concludes that weanlings require 33–42 g/d lysine, and 48–50 g/d is required by yearlings, and that lysine amount should be 4.3% of the CP requirement. Threonine has been suggested to be the second-limiting AA, and dietary intake of about 33–39 g/d together with an adequate lysine intake is deemed to be sufficient for weanlings to a proper muscle gain owing to an assumed improvement in AA balance.

Regarding methionine, there is not a consensus if it is a limiting AA also in weanlings and yearlings or not. It is an important source of sulfur and methyl groups for muscle and connective tissues. However, its content in mare's milk is low. When supplied methionine in excess, it has been reported to inhibit Ca and P reabsorption. Based on studies, 0.035 g/kg BW/d seem to be safe for weanlings and yearlings.

Data on other AA in growing horses is inadequate to establish any accurate recommendations, but some of them are required to bone and cartilage growth and formation. Including protein supplements known as having a good AA content can be assumed to offer adequate amounts also other AAs, as can be approved by calculating the intakes from mare's milk and supplements. Soybean or soybean meal (from soya oil manufacturing) or other by-products of cooking-oil production (rapeseed, linseed, sunflower) and pea and faba bean are common ingredients used to improve the protein content and quality in the foals' diets. The cooking-oil by-products contain also fat providing energy to the diet. Grains and grasses (hay, haylage) are poor in their protein quality and often also in protein amount, which in hays depends on the harvesting time, and do not always meet the requirements of growing horses. Alfalfa and other legumes and their mixtures with hays have instead good protein (and calcium) levels.

Improving the protein quality also decrease the total protein need resulting in reduced N excretion via urine and dung, and thus leaching and evaporation into environment. In addition, protein is an expensive component of nutrition. Studies show that if the AA pattern (protein quality) and availability in the ration meets the requirements of the foals, the CP intake can be reduced from the current recommendations, having positive environmental effects.

Key Notes

- Mare's milk covers the most part of the nutritional requirement of foals during the first 3 months of life.
- Nutritional needs and feeding management, meaning proper nutrition of weanlings and yearlings to ensure their normal and healthy growth and development, are crucial regarding bone health and development.
- Studies show that ad libitum and excess energy fed foals have often a higher occurrence of conformational and musculoskeletal abnormalities than those fed restricted diets. Foals and yearlings with skeletal abnormalities or at risk should not be overweight.
- Excess weight on bones and joints of a growing horse is more detrimental than being underweight. Monitoring the BCS of the growing horse is a good tool for the assessment of overweight in foals.
- Avoiding excess energy, especially to foals that may be genetically predisposed to bone abnormalities, may benefit from diets of lower energy density. Regulated individual and balanced feeding is an important factor to prevent the risk for bone abnormalities.
- When energy intake is regulated, both concentrate and forage intake must be controlled, and the diet be adjusted to meet the needs of other essential nutrients for growth and development.
- If growth is reduced by restricted energy intake, this may result in compensatory growth later. For example, compensation of reduced growth during winter feeding season will occur on pasture.
- Fluctuating growth – rapid growth rate and growth spurts – has been suggested to be related to the increased risk DOD. Avoiding fluctuations may reduce the risk, although it is unlikely that an absolutely smooth growth curve can be achieved because nutrition is the only one factor affecting the growth pattern.
- The recommendations in the literature for extra energy due to cold weather are only indicative. The needs depend on the ambient temperature, management system and age and weight gain of the horse as well as on group dynamics. Also, precipitation and wind must be considered.
- Several studies show that weanlings are sensitive to protein level and quality, and young growing horses require high-quality protein. Increased growth in response to an increasing dietary protein level can only occur when essential AAs are the limiting nutrients for growth.
- Lysine is an intensively investigated AA in horses, and the detrimental effect of its inadequate supply on growth is well documented in the literature. Studies show that lysine supplementation improves the growth of weanlings, and weanlings are most sensitive to protein quality and amount before the age of 8–10 months.

3.3.3 Mineral and Vitamin Requirements and Supplementation

Foal's health and growth and development of bones require dietary minerals and vitamins in appropriate amounts. Minerals are structural components in bones and cartilage and enzymes influencing bone metabolism. Calcium, phosphorus and magnesium are the most important components of bones where more than 99% of Ca, 80% of P and 60% of Mg are stored. Copper and zinc are involved in collagen and proteoglycan synthesis in bones and cartilage. However, it is important to notice that mineral intake alone does not increase the bone density, but mineralization and bone formation happens only when young horses are exercised regularly.

Bone mineral content is increasing up to approximately the age of 4 years, and both adequacy and balance of mineral affect the bone development. Monitoring (feed analysis) of mineral contents in the feeds is important to balance and supplement the diet correctly and individually.

3.3.3.1 Minerals

Calcium (Ca) and Phosphorus (P)

Skeleton of the horse is a store of calcium (Ca) and phosphorus (P). These two minerals are perhaps the most studied minerals in growing horses because they have a large impact on bone development and quality. According to NRC (2007), absorption of Ca in growing horses may be 70% but is declining with age. Absorption of P is lower, 30–55%, but may be better (45%) in younger foals compared to older ones. Recent studies conclude that inorganic phosphorus supplementation for growing horses can be reduced.

The Ca:P ratio in the bone is about 2.0:1. Studies show that low Ca diets for several months after weaning inhibit bone growth and decrease bone mineral content, and that the incidence of OC in weanling and yearlings is high with deficient intakes of Ca and P.

In addition, Ca and P interact in many ways in the body. For example, high Ca intake inhibits P uptake from the gut, and a high P intake may decrease the absorption of Ca, both due to the formation of Ca-P salts. Ca, in turn, interferes with the absorption of phosphorus, magnesium (Mg), Zinc (Zn), manganese (Mn), as well as iron (Fe) and iodine (I).

Other Minerals

Copper (Cu) has a role in the development of cartilage, and Cu deficiency may be a nutritional factor in the incidence of OC in foals. According to studies, foals fed with low Cu levels may have cartilage abnormalities. Copper is stored during gestation into the liver of the fetus and supplementation of Cu in the pregnant mare increases the copper concentration in the liver of the foal. These liver stores of Cu are essential for the healthy bone formation of a young foal, because the Cu supplementation of the lactating mare doesn't influence the milk Cu concentration, and thus the Cu intake by the foal. In addition, the Cu absorption from the ingested feed by the foal is poor. Consequently, attention should be paid on the appropriate Cu intake of pregnant mares. Zinc acts in bone metabolism and in antagonism in Cu absorption.

Other important minerals for growing horses are selenium (Se), silicon (Si) and manganese (Mn). White muscle disease (WMD) is a nutritional myopathy caused by Se deficiency. Common symptoms are muscle weakness, inability to rise, impaired locomotion, lethargy and inadequate suckle reflex. Selenium acts together with vitamin E. However, not all foals low in serum Se and Vit E levels develop the disease, which suggests that individual factors (such as exercise load and other stressors) are also of importance in pathogenesis of the disease.

Manganese is needed for the formation of chondroitin sulfate which is critical for cartilage formation and metabolism. Its intake under recommendations may result in decreased growth. Silicon is important to both bone and cartilage development and metabolism.

Sources and Supplementation

Mare's milk is a natural source of Ca and P for foals and feeding of these minerals to lactating mares is important to maintain their mineral reserves. Versatile mineral supplementation of foals is recommended, depending on the mineral status of the solid foods which the foal is ingesting before weaning. After weaning, supplementation may also be needed depending on the mineral contents of the basal feeds to meet the requirements. Tables 3.1 and 3.2 give the recommendations by the German recommendations. As in other nutrients, there are differences between national recommendations applied in different countries (e.g., NRC/USA, Gfe/Germany, INRA/France).

Increasing exercise and workload increases the bone formation and mineralization. Thus, supplementing Ca at the onset of training may be beneficial to retention

Table 3.1 Mineral recommendations (per day) for growing horses (adult weight 500 kg) after weaning (adapted from Gfe 2014)

	Ca g	P g	Mg g	Na g	K g	Cl g	Fe mg	Cu mg	Zn mg	Mn mg	Se mg	I mg
7–12	31.0	19.9	4.2	3.0	11.0	1.7	490	75	315	315	1,05	1,05
13–18	28.0	18.0	4.8	3.0	12.6	1.7	545	85	355	355	1,20	1,20
19–24	24.2	15.6	5.2	2.9	13.5	1.7	485	95	385	385	1,30	1,30

Table 3.2 Vitamin A, D and E recommendations per day for growing horses (adult weight 500 kg) after weaning (adapted from Gfe 2014)

	Vitamin A IU	Vitamin D IU	Vitamin E mg
7–12	17,000	5100	
13–18	22,000	5900	
19–24	25,500	6000	

IU International unit

of Ca and bone growth. Increased P intake may also increase P retention and is needed to maintain the correct and recommended Ca:P ratio in the diet, as well (see Chaps. 4 and 6).

It is important to have certain dietary balance between Ca and P. Diets with more P than Ca can result in Ca deficiency due to P's negative effect on Ca metabolism and demineralization of the bone, when Ca retention into bone is interfered. Dietary Ca:P ratio for weanlings is recommended to be adjusted to be about 2.5:1 to 1.4–1.2:1, at its lowest. However, horses tolerate high Ca-intakes, and any ratio between 1.1:1 to 6:1 should be considered safe (see Chap. 6). It has to keep in mind that proper mineralization of the bone and Ca deposition requires exercise and loading of the bone. Short prints are considered to stimulate bone formation, while longer distances with slower speeds are not so efficient.

Mineral contents of plants are widely fluctuating depending on soil, plant species, fertilizing, etc. The pH of the soil is influencing the mineral intake of plants, for example Cu and Zinc are taken by the plants with a pH optimum of 5.5–6.5 in the soil. Legumes (clovers, alfalfa) are rich in Ca, and cereals and their by-products (e.g., brans) contain a lot of P—however this being in phytate format in which P is poorly available. Also, availability of Zn is poor for the same reason.

Some research suggested that Ca and other mineral needs are increased when consuming diets with high fat and fiber which may alter the availability of minerals for bone development because of nutrient and chemical interactions (fat forms calcium soaps binding Ca; fiber tends to capture cations).

Many other minerals interact with each other in the digestive tract of the horse, and can then impact each other's absorption. However, not very precise ratios of various minerals are not confirmed by research. Balance between copper and zinc (Zn:Cu ratio) is another important relation between two minerals in foal's nutrition. However, studies show that only extremely high Zn intakes in relation to Cu intake impair Cu absorption. Recommended Zn to Cu ratio in the diet of weanlings and yearlings is about 3.2–5.0. Horses are relatively tolerant to high Cu intakes.

Selenium (Se) is recommended to be supplemented in Se deficiency areas and countries. Horses appear to be more susceptible to Se toxicity compared to other animal species. Selenium is supplemented to fertilizers in some countries and commonly to mineral concentrates.

It is more important to feed the horses balanced ration rather than increase intake and supplement of a single mineral. For example, free-choice supplementing of Ca doesn't ensure adequate intake of Ca. Balancing the diet for minerals is important to prevent detrimental interactions and deficiencies in the animal but also to avoid leaching of minerals to the environment. All supplementing is necessary to be based on feed and soil analyses.

Different feeding standards apply various ways to give the recommended intakes: per ingested feed DM content or based on the age or weight of the foal.

3.3.3.2 Vitamins

Vitamins are important for the metabolism of growing horses. However, very accurate recommendations are missing or recommendations are based on very limiting data. There is a consensus that an effective way to assure adequate intake of vitamins is to allow access to good-quality pasture. Preserved forages (hay, haylage) may also be good sources of vitamins if harvested and stored properly—they have to be leafy and stored away from light. After harvesting, the forages begin to lose their vitamin (or provitamin) contents, and supplementing is often needed during indoor feeding. Both over- and under-feeding have been avoided.

Vitamin A is important for bone metabolism. It has also a role in maintaining immune response to infections, and low vitamin A status has been found to be associated with respiratory infection in weanlings. No supplementation is needed during grazing because pasture plants contain good amounts of beta-carotene (provitamin A). Supplementation is recommended when preserved forages and those lost their green color are fed. Vitamin A is toxic if over-supplemented causing, e.g., ataxia and hyperextension of various joints. Very large overdoses of vitamin A have been shown to stimulate bone resorption and inhibit bone formation in some other animal species.

Vitamin D is acting in skeletal, especially in Ca homeostasis and Ca and P metabolism stimulating the mineralization of the bone and cartilage and is, thus, important to growing horses. It is synthesized in the skin during exposure to sunlight, but horses rely on diet as their primary source of vitamin D. Preserved forages are very low in vitamin D and supplementing of weanlings and young horses that are kept inside is recommended.

Vitamin E acting together with selenium has an important antioxidant function and protects cell membranes against oxidative damage due to free radicals. Adequate intake and supplementation are proposed to be necessary for growing horses by NRC (2007), but specific vitamin E needs for growing horses have, however, not been defined. Addition dietary fat containing polyunsaturated fatty acids (PUFA), e.g., oils from soybean, corn, rape and flax seed, etc., have been suggested to increase the supplementation need of vitamin E.

Vitamin K is involved in the bone formation and metabolism, and is that's why also important to growing horses. The consumption of vitamin K increases when the bone formation accelerates. However, no relationship between vitamin K status and skeletal measures have been found in horses, and no information about requirements are available.

Key Notes

- Ca and P are perhaps the most studied minerals in growing horses because they have a large impact on bone development and quality. Studies show that low Ca diets for several months after weaning inhibit bone growth and decease bone mineral content.
- It is important to notice that mineral intake alone does not increase the bone density, but mineralization and bone formation happens only when young horses are exercised and loaded regularly.

- It is important to have dietary balance between Ca and P. Dietary Ca:P ratio for weanlings is recommended to be adjusted to be about 2.5:1 to 1.4–1.2:1, at its lowest, but horses tolerate high Ca-intakes, and any ratio between 1.1:1 to 6:1 should be considered safe (see also Chap. 6).
- It is more important to feed the horses balanced ration rather than increase intake and supplement of a single mineral. For example, free-choice supplementing of Ca doesn't ensure adequate intake of Ca.
- Balancing the diet for minerals is important to prevent detrimental interactions and deficiencies in the animal but also to avoid leaching of minerals into the environment.
- There is a consensus that an effective way to assure adequate intake of vitamins is to allow access to good-quality pasture. Preserved forages (hay, haylage) may also be good sources of vitamins if harvested and stored properly—they have to be leafy and stored away from light.

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Feeding Growing Race Horses in Work

4

Andrea Ellis and Markku Saastamoinen

Abstract

Work or exercise apparently increases the demand for energy more than for protein. The energy content of diets has traditionally been increased by supplementing rations with grain and other starch-rich concentrates. This leads to large intakes of non-structural carbohydrates (NSC) predisposing horses to metabolic and digestive problems. High dietary NSC contents decrease the microbial digestion in the hindgut also in healthy horses and are associated with higher incidence of osteochondrosis and stomach ulcers. To maintain a healthy digestive tract and good welfare of young horses in training, an adequate supply of structural fibre is required when stabled – a minimum level of at least 1.5% of BW as forage feed (DM) is recommended. High calcium intake is beneficial to bone mineral content especially at the beginning of their breaking and training. However, mineral intake alone does not increase the bone density, but mineralization happens only when young horses are exercised regularly. Supplementation needs of fat-soluble vitamins are needed depending mainly on the diet composition and forage quality. Regarding B-complex vitamins, stress conditions at the onset of training may reduce their adequate synthesis under the needs.

Keywords

Energy and protein needs · Vitamins · Nutrient supplementing

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4.1 Introduction

The athletic demands we put on horses in the racing industry require 1.5- to 3-year-old still-growing horses, to be worked well above light exercise level. Nutrition during the first 2 years of the young horse's life has a greater impact on the growth than in older horses because muscle and adipose growth are most significant just during the first 2 years. After that the growth speed is flattening. In addition, young horses are increasingly kept in open stable systems which increase their voluntary exercise. Therefore, the nutrient needs for such horses consist not only of maintenance, voluntary activity (play, group interaction) and growth but also of requirements for work. This leads to increased requirements for all nutrients. It will increase the load-bearing qualities of the musculoskeletal system, but if training and nutrition are not optimized, bucked shins, micro-fractures, haemorrhage and stress fractures may occur.

4.2 Energy Requirements and Feeding

Energy requirements of young growing horses consist of needs for growth and increased activity due to systematic exercise. In the various energy systems applied in different countries, the requirements of the growing horse are increased by additional requirements for exercise. The increased energy demand of young growing horses in light training is approximately 15–20% above that compared to the non-trained horses (INRA 2015; GEH 2014; NRC 2007).

The NRC (2007) gives separate tables with nutrient requirements, while other energy systems advise adding growth requirements to energy requirements for maintenance and work. Table 4.1 shows the recommendations given by NRC (2007) for growing working horses (at the ages of 18 and 24 months) and requirements for an adult horse at the same body weight. The demand for growth is larger for the 18-month-old horses compared to the 24-month-olds because of their greater growth. In the German ME (GfE 2014) system, 1.3–1.4 times more energy requirement is estimated for Thoroughbred horses in training. This is equivalent to 'moderate exercise' in the NRC (2007) system and no doubt refers to short-term intense exercise. When adding the energy requirements for growth to this, the additional required energy above pure bodyweight maintenance is 1.7–2.0 times maintenance at light to moderate work at 18 months of age. For the same work levels at 24 months, this reduces to 1.5 to 1.7 × maintenance as growth slows down. Overall, there is good agreement between systems despite the use of different energy units (see also Chap. 3). Exercise may also increase the voluntary feed intake of young horses, and the dry matter intake is estimated to be 2.5–3.0% of body weight (BW) for young horses in work.

The energy content of diets has traditionally been increased by supplementing rations with grain and other starch-rich concentrates with the aim of achieving optimum growth in racehorses. This leads to large amounts of non-structural carbohydrates (NSC) in the feed portion predisposing horses to metabolic and digestive

Table 4.1 Energy requirements of an adult horse at estimated body weight (BW) equivalent to a growing horse in work (mature BW 500 kg) (adapted from NRC 2007)

Age	Body weight (kg)	Work level[a]	DE adult (Mcal)	x maint.[b]	DE growing (Mcal)	x maint.[b]	DE increase for growth (%)	DE increase from maint. for work adult (%)	DE increase from maint. for work growing (%)
18 months	380	Maintenance	12.7		19.2		52		
		Light	15.2	1.2	22.1	1.2	46	20	15
		Moderate	17.7	1.4	25.0	1.3	41	40	30
24 months	430	Maintenance	14.3		18.7		31		
		Light	17.2	1.2	21.8	1.2	27	20	17
		Moderate	20.1	1.4	24.8	1.3	24	40	33
		Heavy	22.9	1.6	27.9	1.5	22	60	49
		Very heavy	27.2	1.9	32.5	1.7	19	90	74

[a]Maintenance is calculated at a moderate level for adult horses
[b]Increase from maintenance (= x maint.)

problems. High dietary NSC contents decrease microbial digestion in the hindgut also in healthy horses and are associated with a higher incidence of osteochondrosis and stomach ulcers.

To maintain a healthy digestive tract and good welfare of young horses in training, an adequate supply of structural fibre is required when stabled – a minimum level of at least 1.5% of BW as forage feed (DM) is recommended with a daily optimum DM intake of 2.0–2.5% of BW. Research in racing trotter horses highlighted that high sugar and starch meals are not necessary for optimum growth and performance and that yearling trotters can grow, train and maintain their BCS on a forage-only diet when the forage is of high quality (11 MJ ME/kg; 12.9 MJ DE/kg DM and 150 g crude protein/kg DM). Also, adult trotters in training can be maintained on a forage-only diet and perform at a comparable level as those fed a typical forage-concentrate diet. Some feed manufacturers have responded to the need of minimizing the starch intake by producing lower starch concentrates for racehorses. Caloric intensity can be increased also by dietary fat (vegetable oils) supplementation. This indicates that it is possible to minimize the need for supplementing the performing horse with starchy concentrates, provided that the nutritional quality of the forage is high, a balancer with additional high levels of essential amino acids, minerals and vitamins is all that is required.

An ideal environment for young horses is still being turned out on the grass, which can add another 10% of energy required to their needs due to play and foraging behaviour. Yearlings out on pasture will develop an optimal hindgut environment (pH), with a good balance between the majority of cellulolytic bacteria and some lactate producers. Anecdotal evidence and some reviews show that even high-level competition horses are successful while living 'outside' or grazing for several hours per day, and that through this the negative impacts of confinement on tissue strength can be avoided (see Chap. 6).

Unfortunately, most racehorses trained for flat racing will be stabled for convenience, although they may only leave their stable for a maximum of 1.5 hours/day. Young trotters, especially in Nordic countries, are increasingly kept outdoors after weaning and during the beginning of training. Young horses managed in these systems require additional energy for heat production and play. Additional energy is thus recommended for heat production during cold seasons. The amount of the extra energy depends on the ambient temperature and management system (type of shelter etc.) as well as age and weight gain of the horse and on group dynamics, but energy requirements for exercise are unlikely to be affected by low temperatures. According to studies, the thermoneutral zone has been defined as between 0–5 °C and 20–25 °C in horses. The additional energy requirements for growing light horses (18–36 months old thoroughbred type and standardbred horses) may vary between 0.7% more DE per degree below 0 °C and up to 2.5% per degree below −11 °C (see also Chap. 3). To provide optimum energy for heat production, good quality hay and/or oats are the best choice, because digestion of fibre produces heat. However, in some cases, the horses can spare energy for heat production by decreasing the amount of voluntary exercise, when, in fact, their energy intake may decrease, but this may lead to lower weight gain.

4.3 Protein Requirements and Feeding

Work or exercise apparently increases the demand for energy more than for protein, because exercise increases weight gain and muscle mass. This means that it is necessary to take care of adequate protein intake and protein quality (essential amino acids) of the growing horse. Excessive protein consumption may increase sweating and urine excretion, which may increase the loss of minerals and water-soluble vitamins and disrupt the mineral balance of the growing horse. This may restrict the use of only-forage diets because early-cut high-energy grass (haylage) often contains also high amounts of CP. Feeding horses on legume-based forage like alfa-alfa (Lucerne) hay only is not recommended for this reason. In addition, there would be an excess supply of calcium leading to imbalances. But legume-based forage or pellets can be a valuable large component of the diet.

Table 4.2 shows protein requirements for working horses according to NRC (2007). The recommendation is about 80–90% and 50–80% more CP above maintenance only for horses of 18- and 24-month-old in light and moderate exercise, respectively. For young horses in training, protein requirements have in practice often increased linear with energy requirements, and this may be useful especially in the first year of training. In the s system, the ratio protein/energy ranges from 34 to 40 CP/Mcal DE with a lowest increase at very heavy exercise level (34 g CP/Mcal) for 2-year-old horses. However, this exercise level will not be reached for any type of horses in flat racing or trotting training. In the German and French systems, pre-caecal digestible protein intake is now estimated as it is closer to the actual available crude protein for horses (GfE 2014; INRA 2015). By calculation, the increase for an 18-month-old Thoroughbred for growth above maintenance only comes to 30% and for moderate training above maintenance comes to 40% resulting in a 70% increase in pre-caecal digestible CP requirements – this is less than the 90% increase recommended in NRC (2007) above maintenance of BW only. However, additional increments of 10% may be added for environmental factors.

As the horse is still growing and building muscle, lysine requirement is of particular interest. However, in the NRC (2007) system, lysine requirements are directly linked to crude protein (CP) requirements (lysine (g) = CP (g) × 0.043) (see also Chap. 3). Therefore, the percentage increase in CP and lysine requirements from an adult to a growing working horse are the same (Table 4.2).

4.4 Mineral Requirements and Supplementation

The goal of most breeders and trainers is to raise intensively young horses to meet early maturity before riding in intensive training and racing. Bone disorders can occur during the first postnatal year or/and later. Osteochondrotic lesions which occurred during the first postnatal year can disappear by 18 months depending on environmental factors such as raising management (indoor vs. outdoor), nutrition and exercise (training). Bone mineral content is increasing up to the age of 4 years, and both adequacy and balance of mineral affect the bone development. Keeping young horses outdoors seems to have a strong protective effect. This is mainly due

Table 4.2 Protein requirements of an adult horse at estimated body weight (BW) equivalent to a growing horse in work (mature BW 500 kg) (adapted from NRC 2007)

Age	BW (kg)	Work level	CP adult (g)	x maint.[a]	CP growing (*g*)	x maint.[a]	CP increase for growth (*g*)	CP and lysine increase for growth (%)
18 months	380	Maintenance[b]	466		799		333	71
		Light	517	1.1	856	1.1	339	66
		Moderate	568	1.2	906	1.1	338	60
24 months	430	Maintenance	541		770		229	42
		Light	600	1.1	829	1.1	229	38
		Moderate	659	1.2	888	1.2	229	35
		Heavy	740	1.4	969	1.3	229	31
		Very heavy	863	1.6	1091	1.4	228	26

[a]Increase from maintenance (x maint.)
[b]Maintenance is calculated at moderate level for adult horses

to the additional strengthening of the musculoskeletal system through playing and foraging exercise in contrast to being stables 24/7. In addition, exercise improves stress-bearing characteristics (bone density and metacarpal circumference) in young horses. However, at the onset of training, OD conditions may begin to manifest themselves in lameness and joint swelling. This may have been influenced by nutrition and exercise at a younger age (see Chap. 3).

In the NRC (2007) system, there is an additional increase in calcium requirements for growth of 9%, but there is no increase in phosphorus requirements, and for both, there is no additional increase according to workload. However, high-speed exercise might have a great influence on bone metabolism, which should be taken into consideration when training concepts are developed for young racehorses. During the early stages of training, bone Ca may be used to meet the needs of muscles during their growth, which means that all the Ca removed from the bone is not available for the future bone deposition causing increased requirement of Ca.

It seems that high Ca intake is beneficial to bone mineral content especially in young growing racehorses at the beginning of their breaking and training. Studies show that the bone density first decreased at the onset of training or during a new level of training for around 30 days – therefore training should increase in steps (one-step increase – remain at this for at least 30 days before increasing again). The first 60 days of training horses are particularly vulnerable to conditions like bucked shin, if the increments in exercise are raised too fast. This means that the bones have a decreased ability to resist stress before the bone density starts to increase again as a consequence of exercise, when serum Ca and P concentrations decreased as the minerals were needed for bone formation. Thus, it is important to notice that mineral intake alone does not increase the bone density, but mineralization happens only when young horses are exercised regularly.

An increase in Ca retention may be advantageous to bone remodelling process and overall skeletal growth. The current NRC (2007) recommendations have to be applied (Table 4.3) to guarantee appropriate dietary Ca intakes for growing horses

Table 4.3 Mineral requirements of 18-month-old lightweight horses in racing training at optimum growth rates (BW 448 kg) (INRA 2015; NRC 2007)

	Ca (g)	P (g)	Mg (g)	Na (g)	Cl (g)	K (g)	Cu (mg)	Zn (mg)	Co (mg)	Se (mg)	Mn (mg)	Fe (mg)	I (mg)
INRA Light work	38	27	7	13	43	33	98	488	2	2	390	780	2
INRA Moderate work	38	27	7	17	50	37	98	488	2	2	390	780	2
NRC Light work	37	21	12	11	37	20	97	388	0.5	1	387	484	3.4
NRC Moderate work	37	21	12	14	42	23	97	388	0.5	1	387	484	3.4

during early training, but some studies show even higher needs may be depending on the breed and age (e.g. the growth and development pattern, see Chap. 2) as well as the type of training of the horse.

No benefit from increasing dietary P other than to maintain the optimal recommended Ca:P–ratio (1.7–2.0) has been found. The increased need for dietary Ca and P seems to be most obvious approximately 3 to 4 months after training has begun; naturally, this is depending on the intensity and type of training. Energy sources fed have also some impact: high fat and fibre intakes may increase the need of Ca (and other minerals) because it may decrease their absorption from the digestive tract in growing horses.

Magnesium needs of young horses are not well studied, but comparing the NRC recommendations (NRC 1989 vs. 2007), the recommended intakes were increased such that the current NRC recommendation of Mg is 12.9 g/d for a 500-kg horse (adult weight). It also has to be considered that high dietary Ca and P intake might depress Mg metabolism.

The increase in body mass as a result of growth and training also results in an increase in the blood volume of the horse. This highlights the increased needs for iron (Fe) and copper (Cu), as well as other trace minerals required for muscle's growth and health and blood formation. Selenium (Se) may reduce cellular damage caused by exercise stress. However, optimal levels of Se in diets of young horses have not been thoroughly investigated during times of increased oxidative stress such as simultaneously occurring growth and training. Some studies recommend complexed trace minerals to maintain muscle health in young horses in training and competing rather than inorganic trace minerals.

The horse loses minerals called electrolytes through sweating and urinating. Sweat loss will be particularly affected by humidity and temperature as well as intensity and duration of exercise. In addition, increased water intake will result in increased excretion of urine and sweat. High-fat diets may reduce heat load in hot weather.

Sodium, potassium (K) and chloride (Cl) are the three main minerals which are lost considerably from sweat and these need to be replenished. The electrolyte supplementation can be given after sweating. For the young working horse, maintaining a good electrolyte balance (balanced to mimic equine sweat) is very important, and therefore, supplements or avoidance of feeding 'unbalanced' straight feed may be recommended. Failing to balance supply of electrolytes with the rest of the ration can results in mineral imbalances, delay exercise recovery, and might not encourage rehydration. Free-choice access to salt is also recommended to compensate the loss of electrolytes (Coenen 2005).

4.5 Vitamin Requirements and Supplementation

There are no precise recommendations for vitamin nutrition for growing horses in work. Pasture grass and preserved forages (hay, haylage) may be good sources of vitamins if harvested and stored them properly. Concerning this group of horses, however, some factors may need to be taken into account.

Vitamin A is important in maintaining the integrity of mucous membranes, and these tissues are certainly put under quite hard stress also in young exercising horses, particularly when the training is carried out in wintertime in cold weather. It may also be important for immunity together with Vitamin D. Thus, the vitamin A requirement of exercising young horses may be higher compared to horses at rest. However, studies with some other animal species show that very high overdoses may stimulate bone resorption and inhibits bone formation.

Vitamin D is mainly involved in the metabolism of calcium and phosphorus and to a lesser extent magnesium metabolism. There is a possible increased need of vitamin D for Ca absorption from the small intestine to allow for the increase in bone formation (increased bone modelling) which results from increased amount of physical activity in young horses entering training. In the case of P, accelerated bone formation leads also to higher phosphorous absorption rates. Vitamin D is synthesized in the skin during exposure to sunlight, but horses rely on diet as their primary source of vitamin D. Because studies show that preserved forages are very low in vitamin D, supplementing of young horses that are kept inside and fed with preserved forages is recommended. No difference in the needs of supplementation has been found between blanketed and non-blanketed horses.

Vitamin E is important to the muscles of exercising horses acting as an antioxidant. Vitamin E has a role in protecting cells against oxidative damage, and it acts together with Se, and adequate intake and supplementation are proposed to be necessary for growing horses by NRC (2007). However, specific needs for growing horses in training have not been defined, but supplementations recommended to exercising horses can be applied also to young growing horses. The addition of dietary fat containing polyunsaturated fatty acids (PUFA), e.g. oils from soybean, corn, rape and flax seed etc., has been suggested to increase the supplementation need of vitamin E.

In addition to homeostasis, vitamin K is involved in bone mineralization, remodelling and metabolism. Vitamin K is synthesised in the colon by the endogenous microflora. A good source of vitamin K is green grass and forage harvested and preserved properly. It is possible that consumption and need of vitamin K is increased at the beginning of exercise training of young horses with increasing bone loading resulting in accelerated bone formation.

Vitamin C (ascorbic acid) can act directly as an antioxidant preventing radical-induced oxidative damage. It is synthesized by the horse itself, but decreased synthesis due to stressful conditions and infections may increase the requirement for vitamin C.

B-complex vitamins are vitamins synthesized by intestinal microorganisms and are normally present in adequate amounts in feeds to meet their requirements. However, it is possible that changes in ration, intense exercise and other stress conditions at the onset of training may change the synthesizing organism population to reduce adequate synthesis of these vitamins under the needs.

Key Points

- Work or exercise apparently increases the demand for energy more than for protein.
- Large portions of grain and other starch-rich concentrates lead to amounts of non-structural carbohydrates (NSC) which predispose horses to metabolic and digestive problems.
- To maintain a healthy digestive tract and good welfare, an adequate supply of structural fibre is required when stabled – recommended daily optimum DM intake is 2.0–2.5% of BW.
- High Ca intake is beneficial to bone mineral content especially in young growing racehorses at the beginning of their breaking and training.
- Studies recommend complexed trace minerals to maintain muscle health in young horses in training and competing.
- Preserved forages are very low in vitamin D and supplementing of young horses kept inside and fed with preserved forages is recommended.
- It is possible that changes in ration, intense exercise and other stress conditions at the onset of training may reduce adequate synthesis of B-complex vitamins under the needs.

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Feeding Practices of Mares and Young Horses

5

Malin Connysson and Markku Saastamoinen

Abstract

The feeding planning and formulation of feed ration of the growing horse during the indoor feeding season is always based on good quality forages. It is important to plan the diet's forage-to-concentrate ratio, i.e. to optimize the forage intake from the health and welfare perspective of the horse. During summer, whole-day grazing is generally recommendable to promote the health and welfare of horses, and to support their natural behaviour. To know how the diet can be properly balanced with supplemental feeding, the nutrient content of feeds must be known. Thus, a forage analysis is crucial for the successful use of diets dominated by forage. It is also important that all fibre sources are high in their hygienic quality, influenced mainly by their storing. Also, if horses are fed in groups, their individual needs have to be considered applying individual feeding, especially if the group consists of horses of different sizes and breeds.

Keywords

Foraging · Grazing · Feeding planning

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5.1 Introduction

Management and feeding practices of young horses during the first years of life vary due to many factors. There are geographical and seasonal differences because of the variety of feeds between the seasons and areas. The breed and horse's further use, time of breaking, and different traditions are also affecting. Feeding horses outdoors in winter and cold climates presents a challenge to horse owners and stable managers in the northern latitudes: low temperatures, harsh winds and rain, snow and ice all contribute to increased nutrient requirements.

However, as a "herd animal", horse spends about 60% of its daily behaviour and activities on voluntary food intake. The horse is by its evolution adapted to ingest forage and low starch diets, and it requires dietary fibre in the form of forage for proper digestion and gut health. In spite of this, horses are mostly stabled individually with restricted feed availability.

The energy requirements of growing horses consist of energy needed for maintenance and for growth (see Chaps. 3 and 4). For growing horses that start training at a young age (mainly racing horses), energy is also needed for work. Maintenance requirements are the nutrients required to maintain body condition and metabolism during every day activities like eating, search of feed and water and to keep on social contacts. Maintenance energy requirements are varying between individuals and are affected by body composition, excitability, and ambient temperature. The growth happens always individually although different growth curves can be seen for various breeds (see Chap. 2).

Today, people are more concerned and aware of horses' behavioural needs, and free barns with automatic feeders or more frequent access to feeds are coming more and more popular especially in managing young horses, also those in training. Whatever the feeding practice has been chosen (stabling, loose/group housing, pasture supplementing), the intakes have to be adjusted individually.

5.2 Water Intake

Water is the nutrient that is most important for all horses. The horse body contains 60–70% water and maintenance requirement of water is approximately 5–6 L per 100 kg BW, but the water consumption increases during warm weather, training, and lactation. The horse mainly loses water in faeces, urinating, evaporation, sweating, and milk production. In addition, feeding horses a diet containing a large amount of forage has been shown to increase water intake compared with a diet with limited forage intake.

Feral horses have been shown to walk very long distances to drink water and thereby have a drinking frequency of 1–4 days between water intakes. In the wild, water holes are also a good place for predators to hunt, so horses drink fast and move away to avoid being killed by predators. Horses kept by humans should, however, always have access to water. The water provided to horses should be of good hygienic quality. Horses prefer to drink from a calm water surface than from a messy water surface. Drinking water from a bucket is preferred over drinking water from automatic drinking bowls, and if automatic drinking bowls are used, the flow rate should be around 8 L per minute. During cold conditions, it is important to provide water that is not frozen; to do that, isolated and heated water barrels can be used. Horses drink most in connection to eating, so it is important to provide water during feed time. However, restricted access to water is one risk factor for colic in horses and should therefore be avoided.

Horses do not only get water from drinking but also from feed and from metabolic water. Grass, for example, contains up to 80% water. Thus, during grazing season, the horses eat most of the water consumed. In the same way, a high dry matter content forage (hay) increases drinking water intake, while a lower dry matter content forage (silage) decreases it. In case of a low water intake, water can be fortified with small amounts of sweet feed (e.g. 100–200 g compound feed in 20 L water) as horses prefer sweet feed-flavoured water compared with plain water. Offering a horse slightly salted (1 g/1 L) water immediately after exercise stimulates the horse's thirst centre and can encourage it to drink.

5.3 Feeding Planning

In most feeding practices of lactating mares and young growing horses, summer feeding is based on grazing. Thus, planning of feeding a horse starts with utilizing a pasture which is high in yield and rich in nutrients.

The dietary energy can by derived from carbohydrates, fat, or protein. The proportions of different energy substrates that will be available to the animal are depending on the diet composition. The nutrient needs are presented detailed in Chaps. 1, 3, and 4.

The carbohydrates are either structural or non-structural (NSC). The structural carbohydrates (cellulose and hemicellulose) are digested by microorganisms in the hindgut. The main source of structural carbohydrates for horses are forages, i.e. pasture grass or conserved forages as hay and haylage, or e.g. hay pellets and briquets. Sufficient fibre intake is essential to the proper gut health as well as ingesting behaviour and chewing requirements of the horse. Lack of fibre and decreased chewing result in declined production of saliva and lower pH in stomach, and incidence of gastric ulcers, which may in turn be associated with increased risk of crib-biting.

The non-structural (soluble carbohydrates) consist of starch (in grains) and sugar. They are normally digested in the small intestine by pancreatic enzymes. Excessive amount of starch is a risk for leakage of it into the hindgut and causing disturbed fermentation that can lead to an increased production of lactic acid and thereby result in lower pH of the hindgut.

Some studies show that the energy substrates fed to growing horses may affect their health as an adult. High amount of starch may be a risk factor for abnormal cartilage development in growing horses, and also for insulin resistance and osteochondrosis in genetically predisposed horses. Thus, a diet with a high part of forage seems to be an alternative in the feeding of growing horses. In addition, no negative effect on weight gain and nutrient digestibility when fed high-quality high-forage diets (high forage-to-grain ratio) have been reported. Energy intensity can be increased by feeding dietary fats (oils) and thus substitutes high amounts of non-structural carbohydrates in the diet. Oils have also been reported to reduce post-exercise inflammation and muscle damage in young growing horses in training.

Forages are also sources of other nutrients because the cell content of the plants consists of water-soluble carbohydrates, proteins, peptides, lipids, vitamins, and minerals. Thus, the feeding planning and formulation of feed ration of the growing horse is always based on good quality forages. The nutritional quality of forages is greatly depending on the harvesting time; when grass matures, the proportion of cell wall increases (decreasing the digestibility), and the cell contents decrease.

Although good quality forages contain usually CP in good amounts, their AA profile is often insufficient for weanling horses, concerning especially lysine content. Studies show that forage-based diets usually require a protein supplementation with a protein-rich feed containing the limited amino acids in recommended amounts, and with a good digestibility (see Chap. 2).

Use of Body Condition Score (BCS)

The proper energy intake for maintenance and growth can be quite easy to evaluate since insufficient energy intake will decrease adipose tissue and thereby give a lower body condition score (BCS). On the other hand, an excessive energy intake will increase adipose tissue and result in a higher BCS. Body condition scoring has been developed for adult horses but can preferably be used for growing horses as well, to monitor more accurate energy intake. The scoring point that changes most rapidly is the fat storage at the ribs, here an insufficient energy balance can be detected in a couple of weeks. Even if body condition scoring hasn't been as well documented in growing horses as in adult horses, it is of great importance since all growing horses need to gain body weight. However, it is important to notice that this body weight is not only adipose tissue. There are several BCS systems in different countries, but the so-called Henneke system is the most used (see Chap. 1).

5.4 Indoor Feeding Management

Winter feeding is based on preserved forages, mainly hay and haylage. When pasture season is over, it is important to plan the diet's forage-to-concentrate ratio, i.e. to optimize the forage intake from the health's and welfare's perspective of the horse.

Because the horse is originally a grazing animal spending the most part of the day eating and searching feed, it is important to divide daily feeds into several meals. Studies have demonstrated that horses fed (at any age) only two large grain meals per day will lead to periods of fasting during which the gastric mucosa is exposed to highly acidic conditions (due to a constant production of HCl in the horse's stomach). It is therefore important to spread large concentrate (starchy) meals over at least three meals a day and to ensure adequate intake of forage (fibrious) feed. Feeding forage before grain increases salivation and bicarbonate ions that buffer pH and reduces the acidity of the stomach. It also reduces grain starch fermentation in the hindgut (cecum and large intestine) and increases water flow through the stomach and, thus, the passage rate of the grain bolus.

An early harvested grass/grass-legume forage can contain enough energy and protein to meet young horse's requirements. If the forage is of lower nutritional quality or if the horses are fed straw, some protein-rich supplement must be fed. One good alternative can be lucerne that is a type of forage and that is often rich in both protein and calcium. Other options for protein supplements are, for example, soy meal, by-products of cooking-oil production (rapeseed, linseed, sunflower groats and meals), or potato protein. Pea and faba bean are also common ingredients used to improve the diet and feed protein contents. There are also commercial concentrates that are high in protein. The diets must also be supplemented with mineral supplement (see Chaps. 1, 3, 4, 6). To know what kind of mineral supplement is needed, the mineral content of all feedstuffs in the diet must be known so that total intakes and mineral balances can be adjusted.

5.4.1 Forage Supply

Since horses have a digestive system that is developed for fibre digestion, it is important to provide fibre in some form if there is a lack of dietary forage. To maintain a healthy digestive tract and good welfare of young horses in training, an adequate supply of structural fibre is required—a level of 1.0 to 1.2 kg/100 kg BW as forage feed (DM) is recommended daily, and preferably 2 kg DM forage/100 BW. Lack of fibre intake may be of greater significance than the high intake of concentrates.

Lack of plant fibre intake for horses increases the risk of colic. Since the access to plant fibre is so essential for horses' health, other fibre sources must be added if there is a lack of grass forages. Examples of fibre sources that can be used are, for example, sugar beet pulp, brans, sugar cane fibre, and reed. However, some of these alternative fibre sources provide less eating time which can lead to development of stereotypic behaviours. Some studies have shown that young horses may start stereotypic behaviour during the first few months after entering training. Coprophagy and bedding eating can increase significantly in young horses when stabled on a high concentrate-low fibre (forage) diet. However, eating the bedding straw is a time-consuming activity as well, and may help compensate the lack of forage and other bulk in the diet. It is important that all fibre sources are high in their hygienic quality, influenced mainly by the storing.

For indoor and winter-feeding, forage or roughage can be conserved in different ways. Hay and straw are conserved by drying the crop to at least 84% dry matter, and it is important that the hay and straw are protected from moist to maintain hygienical quality. Another way for conservation is in airtight conditions, for horses most commonly accomplished by plastic wrapping. This kind of forage has a recommended DM content of 50–70% and is called haylage. If conservation of the forage is disturbed, by water in the hay/straw or holes in the plastic wrapping, there is a risk for undesired microbial growth in the forage that can spoil it and cause health problems if fed.

A forage analysis is crucial for a successful use of diets dominated by forage. Depending on the requirements of the individual horses, a careful selection of suitable batches must be done. Many grass hays fed to horses may be relatively mature and thus low in crude protein (CP) and digestibility. Forages with low nutrient content cannot be used as the only feed for brood mares, growing horses, and horses in heavy exercise but early-cut grass hays/haylages may. Mixed forages (legumes and grass) may contain more protein and calcium than grass forages only. This can be considered when diets for brood mares and yearlings are composed and may greatly affect the need for protein and Ca supplementation.

5.4.2 Forage Quality

Forage-based rations consisting of 80–90% forage for young horses after weaning are usually fed, but high-quality forages may comprise 100% of the ration of both mares and young horses. The main challenge is to find forage that covers the protein needs. A "good medium quality" (9–10% CP, 9–10 MJ ME/10.6–11.8 MJ DE) forage covers the protein needs of pregnant mares but may result in declined body condition score at foaling because of its low energy content compared to the needs. It is known that deficiencies in the nutrition of broodmares decrease their milk production and foal growth, since the growth rate depends on the mare's milk production. However, forage-only diets may also cover the needs of lactating mares at the peak of lactation when the feed's nutritional quality is good. For example, hay consisted of timothy, meadow fescue, and red clover with 10.9 MJ ME (12.8 MJ DE), 90 g digestible CP, and 6.8 g lysine per kg DM, as well as timothy-meadow fescue hay with 9.9 MJ ME (11.6 MJ DE), 60 g digestible CP, and 4.8 g lysine per kg DM are such high-quality forages.

If too energy-rich forages (or pastures) are fed ad libitum to non-pregnant, pregnant, or late lactating mares, they may accumulate fat and get obese, which may reduce their fertility. This may also result in large-sized foals causing possible problems in foaling. After weaning, high energy intakes may cause disturbances in bone and cartilage formation (see Chaps. 2, 6). It also increases fat content and weight of the horse. Monitoring the foals' BCS, growth, and development carefully with 2 to 3 weeks intervals is important to ensure adequate and balanced energy intake.

Concerning growing horses in training, studies show that Standardbred yearlings can grow and train and maintain their BCS at around 5 on a forage-only diet when the forage is of high quality (11 MJ ME/kg; 12.9 MJ DE/kg DM and 150 g crude protein/kg DM). This indicates that it should be possible to minimize the need for supplementing the performing horse with (starchy) grains or concentrates.

To maintain horses' health and to guarantee their wellbeing, it is important to take care of the hygienic quality of the feeds and feeding facilities in the paddocks or loose stables. Poor hygienic quality of feeds and feeding may cause severe problems both in gastro-intestinal tract and airways of the horse. Feeds stored and fed outside alter poor climatic conditions and may be a source of many harmful microorganisms.

5.4.3 Feeding Management

Both adult and young horses are mainly housed in individual box stalls. Box stalls facilitate the supervision of horses, individual feeding, and grooming of the horses, but obviously limit their scope for free movement and social interaction. Box stall can be a helpful tool during weaning, if a horse is sick or injured and during education of the young horse in things like grooming and wearing different equipment. During the time in individual box stalls, it can be a good opportunity to give minerals and extra energy and/or protein if needed. This can be valuable if a young growing horse is kept in a paddock with adult horses who don't require high energy and protein requirements. Feeding in box stalls can be automatized by hay and concentrate feeders instead of manual feeding, which enables individual and controlled feed dosing.

Individual feeding indoors can also be done in large group boxes by learning the horses to be tied by their feed tub during feeding. This routine can also be helpful for supervision of the horses. When kept indoors, the horses should also have access to forage and/or straw. Forage should be fed preferably low, to mimic outdoor grazing. When deciding a feeding strategy, it is important to consider forage feeding which gives the horse access to forage during most hours of the day.

Many hours outdoors in groups in paddocks and on pasture is however essential for young horses. In a study on young horses living indoors in stables, with a restricted possibility for voluntary movement, it has been shown to negatively affect bone quality when compared with young horses kept on pasture. This result was the same irrespective of whether the horses were training or not training (see also Chap. 6). Also, insufficient indoor ventilation together with dust from feed and bedding increases the risk of horses experiencing problems with their respiratory system.

Free barns with a sleeping hall and automatic forage and concentrate feeders or more frequent access to feeds are becoming popular especially in managing young horses—also those in training—but weanlings are kept in open barns, too. Although horses are fed in groups, their individual needs have to be considered applying individual feeding, especially if the group consists of different kinds (size, breed) of horses. Some studies show both breed and individual differences in the digestibility of nutrients or energy demands. Some individuals are so called "easy keepers" accumulating fat easily in their body. In addition, the amount of voluntary exercise of horses varies resulting in different energy needs and feeding levels. It is also known that group-housed growing horses are more active compared to individually housed. Eating and feeding are part of the social life of the horses in paddocks and the loose housing systems as well.

In free barns, forage is often available all day long. If the forage quality is not constant, horses may select the most digestible parts of the feed, and voluntary intake of the feed decreases with declining forage quality. However, some horses may compensate for the low nutritional value of the forages by increasing intake, but intake of large amounts of poorly digested feed may decrease the total digestibility of the diet, which may result in declined energy intake.

Foals entering an environment below their thermoneutral zone consume energy above the maintenance needs to maintain their body condition. Thus, in cold weather conditions (see Chap. 3) to provide optimum energy for heat production, good quality forage (hay, haylage) and/or oats are the best choice, because digestion of fibre produces heat. Hay and haylage can be substituted partly by hay cubes. Beet pulp as a part of concentrate portion can also be used as a source of fibre. It is important to check the teeth of the horse and floated them, if necessary, prior to winter feeding, to improve the utilization of the fibrous feed. In addition, young horses are maybe not acclimatized to the cold environment. This is most evident in weanling foals, but challenges the stable staff concerning all young horses, to carefully plan and carry out the feeding.

Horses coming to group conditions and loose housing systems may be stressed if they originate from many different stables and managements. This stress may decrease their feed intake resulting in negative energy balance. If no automatic feeders with controlled access are used, it is necessary to use feeders that allow enough space for each horse in the feeding stations to reduce competition and ensure adequate feed intake for all horses.

5.5 Pasture Feeding

5.5.1 Benefits of Grazing

Grazing has a large importance in horse breeding, because it decreases the costs of horse keeping and offers good and balanced nutrition when taking care of proper management of the pastures. Whole-day grazing is generally recommendable to promote the health and welfare of the horses and to support the natural behaviour of the horses. However, the possibilities of using grazing in horse breeding are not equal in every part of Europe or North America, and are limited for example in the northern latitudes (e.g. Northern European countries, Canada) because of the short growth period of grass and colder weather conditions, compared to Middle and South European countries.

According to some studies, horses maintained at pasture could be expected to have healthy gastric mucosa and effective cellulolytic bacteria activity. This is mainly due to fibre-rich diet and long eating time, when horses spend 16 to 17 h ingesting the pasture grass. Slow ingesting and movement are advantageous to horses of all ages, especially growing ones. Some studies have shown that also high-level competition horses may graze for several hours per day or even for 24 h, which helps with nutrient balance and digestive tract health without impairment of performance.

Yearlings and 2-year-olds have a high compensatory growth capacity which for instance can be utilized during pasture feeding after a winter-feeding period. They, especially fillies, have an ability to accumulate body fat and maintain body weight in summer pastures, and the fat can be mobilized as a source of energy during winter.

There are also other benefits due to grazing in addition to the nutritional ones. Growing horses benefit from playing and voluntary exercise –healthy bone formation and mineralization need loading of the bones (see Chap. 6). Furthermore, studies also show that keeping foals at pasture post-weaning instead of stabling them inside with a restricted opportunity to free exercise in paddocks reduces the risk of developing abnormal behaviour. Continued grazing during the "growing" and training period will help with temperament and prevention of behavioural problems. In addition, grazing horses have a potential in landscape conservation and maintaining the biodiversity of semi-natural pastures when pasturing of other animals has declined.

Horses have a highly selective grazing behaviour, but they consume a wide range of foraging species. Their preferences can also vary during the season. Thus, the real nutrient intakes of the horses depend on the species they eat, because of the differences in the chemical composition and feed values among them. They can select plants of high protein content and graze mostly on areas with the best nutrient value and quality, such as younger and leafy stage vegetation with lower NDF content.

5.5.2 Grazing Management

High-quality, immature pasture can meet most of the nutritional requirements of gestating and lactating mares and foals which require especially high protein levels. Depending on the grass yield, good pasture can also fulfil the energy and protein requirements of yearlings and older still-growing horses. It can be recommended to start grazing of lactating mares latest 2 to 4 weeks after foaling. Early foaling mares are just in the beginning of lactation in spring and early summer, and those foaling in May–July are usually at the end stage of peak lactation in autumn. This highlights the importance of high-quality summer pastures for lactating mares.

From the age of 2 months, foals' growth is not only correlated to milk intake as the growth starts to depend more and more on other sources of nutrients. Foals begin to consume small amounts of solid feeds like grass during the first 10–21 days of life and the amount increases with age (see Chap. 2), although they can ingest pasture and other well-digested plant-based feeds already before the age of one week.

However, the main source of nutrients for sucking foals is mare's milk, and to ensure sufficient milk production, it is necessary to guarantee the adequate availability of early-mature grass on the pasture. The goal is to keep the mares in moderate body condition. If the amount of pasture is limited or pasture quality is low, for example in mountain pastures or uncultivated grasslands, supplementation is needed. Grass, hay, silage, or haylage is usually used as supplemental feeds. Also, grains or pelleted feeds and beet pulp can be used. All supplemental feeds shall be balanced to supplement the nutrient content of the pasture grass. Monitoring sucking behaviour and BCS of the foal are the tools to evaluate the nutritional status of the sucking foal.

Stocking rate is important for the growth of young horses on pasture. A high stocking rate causes high grazing pressure and decreases grass yield and availability. Low grazing pressure, instead, will allow maturation of grasses and, thus, lower their nutritive value, both conditions causing a reduced growth rate. It is possible to apply creep-feeding of foals to supplement the milk and pasture, but it may result in accelerated growth and decreased bone quality and cause bone abnormalities (see Chaps. 2 and 6) if not adjusted individually based on the monitory of the growth. To maintain sufficient milk production if pasture quality or production is not high enough, it is therefore better to supplement the mare. One study demonstrates that sometimes it is also profitable to supplement the pasture grass with a protein supplement to compensate the effects of the fluctuation in the grass amount and quality during the course of the grazing season. This improves the amino acid composition of nutrition and may produce a more even and balanced growth curve of the nursing foals.

Concerning many minerals, several studies demonstrate that it is necessary to supplement pasture diets with mineral supplements, because of the large variation in the mineral contents of the pasture grass, the content depending on the soil type, fertilizing, climatic conditions, and plant species. Mineral supplement rich in calcium is recommended to be given because big amounts of calcium are excreted in the milk. Such a mineral mixture usually contains balanced amounts of other minerals, too. Copper and zinc are important minerals for proper bone development (see Chap. 3). Mare's milk has rather low copper and zinc concentrations, and those minerals in the diet have very little effect on their contents in the milk. It is also recommended to feed salt (sodium) because of the low content of Na in grasses, and because of increasing sweating during hot weather. To ensure that mineral requirements are met, the mineral content of the pasture grass shall be analysed. To analyse pasture grass, samples should be taken from different sites of the pasture and then mixed.

The length of the grazing season (the growth period of pasture vegetation) varies in different geographical areas, and different parts of each country depending on the climatic conditions and the productivity of pastures. Over-winter (year-round) grazing is used in climates where it is possible, although the productivity of the pasture is low. The CP and energy contents during winter months are usually insufficient to cover the growing or pregnant horses' needs and to maintain their body condition, but some vegetation studies show that the CP contents may be higher than needed even in the semi-natural pasture grasses. During the growing season, the pasture grass provides surplus energy which the horses can store as fat to be used in winter. Year-round grazing (mares, young horses) is applied in Europe (e.g. rewilding of horses) in southern latitudes but has applied also in northern latitudes (south of 60 °N) and in Iceland for domestic breeds adapted to colder climates, e.g. Icelandic horse and Gotland russ that can even foal on the pasture. Supplemental feeding is needed at least during the winter times when snow covers the pasture.

Pasture Types and Management

The pastures used for horse grazing are variable, ranging from cultivated pastures to natural rangelands. The rangelands can be divided into many categories, such as lowland and highland or wet and dry areas. Uncultivated natural and semi-natural pastures are used in many countries. These pastures are, for example, wetland and old natural pastures previously grazed by cattle and now grazed by horses for the purpose of conservation biodiversity. Also, mountain pastures are used.

Most of the pastures used for grazing mares and their foals are cultivated field pastures. Semi-natural or natural pastures with forest and different herbs are more usable for other horse categories. Topographically varying natural and mountain pastures offer good conditions for increased physical activity compared to flat field pastures, which makes them suitable to yearlings and older growing horses.

Management practices influence the productivity of the pasture and, consequently, milk production of mares and growth rate of the foals. According to studies, the growth of horses was better on lowland pastures than on mountain pastures. On the mountain pastures, energy intake might be under the requirements due to climatic conditions and increased activity caused by the varying topography. However, the feed values of natural pasture grasses may be as good as those of field pastures, depending on the grass species and their maturity. Measuring of the productivity and monitoring the BCS changes and growth of the horses are necessary to ensure proper nutrient intakes.

The optimum length of the pasture grass for grazing is 15–20 cm. To guarantee the growth and quality of the grass, the cultivated pastures shall be fertilized properly, based on analysis of the soil. Also, irrigation can be used during dry periods. Practical analyses show that the mineral content of the pasture grass has a large variation. This means that grass should be supplemented with a proper mineral mixture.

Both continuous and rotational grazing can be applied. The first method is usually used in small farms with restricted land areas, supplementing the grass with other feeds. The latter method is recommended and ensures proper grass production during the whole summer. Concerning reducing parasitic burden on pastures, see Chap. 6.

Key Points

- The feeding planning and formulation of feed ration of the growing horse is always based on good quality forages (grass, hay, haylage). Because the horse is originally a grazing animal spending the most part of the day eating, daily feeds have to be divided into several meals. When deciding a feeding strategy, it is important to consider forage feeding which gives the horse access to forage during most hours of the day.
- When pasture season is over, it is important to plan the diet's forage-to-concentrate ratio, i.e. to optimize the forage intake from the health and welfare perspective of the horse. To maintain a healthy digestive tract and good welfare of young horses, an adequate supply of structural fibre is required—a minimum level of 1.0 to 1.2 kg/100 kg BW as forage feed (DM) is recommended daily.
- A forage analysis is crucial for a successful use of diets dominated by forage. Voluntary intake of the feed decreases with declining quality. To know what kind of supplement is needed, the nutrient content of feeds must be known so that nutrient balances can be adjusted. It is important that all fibre sources are also high in their hygienic quality, influenced mainly by the storing.
- Many grass hays fed to horses may be relatively mature and thus low in their protein content. Such diets usually require a protein supplementation with a protein source containing limited amino acids. Mixed forages (legumes and grass) may contain more protein and calcium than grass forages only.
- According to several studies, forage-only diets can cover the needs of lactating mares at the peak of lactation and also the requirements of yearlings in training when the feed nutritional quality is good.
- In cold weather conditions to provide optimum energy for heat production, good quality forage (hay, haylage) and/or oats are the best choice, because digestion of fibre produces heat.
- Although horses are fed in groups, their individual needs have to be considered applying individual feeding, especially if the group consists of different kinds (size, breed) of horses.
- Whole-day grazing is generally recommendable to promote the health and welfare of horses, and to support the natural behaviour of the horse.
- High-quality, immature pasture can meet most of the nutritional requirements of gestating and lactating mares and foals which require especially high protein levels. Depending on the grass yield, good pasture can also fulfil the energy and protein requirements of yearlings and older still-growing horses.
- Applying creep-feeding of sucking foals to supplement the milk and pasture is possible but may result in accelerated growth and decreased bone quality if not adjusted individually based on the monitory of the growth.
- Over-winter (year-round) grazing is used in climates where it is possible. The CP and energy contents during winter months are usually insufficient to cover the growing or pregnant horses' needs and to maintain their body condition. Supplemental feeding is needed at least during the winter times when snow covers the pasture.

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Health Risks of Growing Horses Related to Exercise and Parasite Control

6

Brian D. Nielsen, Eva Tyden, Frida Martin, and Ylva Hedberg-Alm

Abstract

In this chapter, health issues related to exercise and parasite control in growing horses are discussed. Concerning problems associated with bone health, the importance of exercise is highlighted, and many of the problems can be avoided by providing a balanced diet and ensuring that the skeletal system is trained properly. Proper nutrition is vital for a healthy skeleton only if the sufficient and right type of exercise is accompanying it. The best opportunity to make the skeleton strong is to provide it with proper stimuli through exercise when a horse is young and growing. Due to their high susceptibility to parasitic disease, anthelmintic treatment in growing horses is advisable without prior diagnostics. For example, any move to a new group, e.g. after weaning, should be performed only after anthelmintic treatment. In foals and young horses, in addition to strategic anthelmintic treatment, management practices aiming to reduce parasite burdens on pastures are especially prudent. Faecal removal twice weekly has been shown to be more effective than anthelmintic treatment. It is advisable to practice faecal removal from any paddocks in use, as long as temperatures are above freezing.

Keywords

Bone modelling · Bone health · Nutrient ratios · Parasite infections · Parasite monitoring · Anthelmintic resistance

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6.1 Introduction

There are many management factors contributing health of growing horses. These have been dealt with in previous chapters. They include nutrient requirements, diet planning and rationing, nutritional and hygienic quality of the feeds, etc. In addition, gastrointestinal parasite infections may cause damage to gastrointestinal tissue and loss of appetite, and thus affect the growth and development of the horse. Concerning problems associated with bone health, many of them can be avoided feeding a balanced diet accompanying with sufficient exercise. Impaired health during the growing period influences detrimentally the later use and performance capacity of the horse. This chapter examines two important health issues, bone health and parasite control. Understanding the risks and detecting the possible problems in both of these within good time prevents the incidence of larger damages.

6.2 Bone Health and Formation: Training Effects and Nutrient Balance (Brian D. Nielsen)

As most horses are bred with the goal of having them develop into an animal that can be ridden or driven, soundness is critical. One important aspect of maintaining soundness is bone health. While many factors contribute to bone health, there are three primary ones that need to be highlighted: exercise, nutrition, and genetics. All three play a crucial role in the development of strong bones, but individuals managing young horses can have the greatest influence on the first two. While most people appreciate the importance of proper nutrition, few fully understand how critical the right exercise is to help transition a young horse into an equine athlete that can withstand the rigors of training. To understand this better, it helps to know how, and why, bone responds to the forces placed upon it.

6.2.1 Influence of Exercise

6.2.1.1 Wolf's Law

While appearing to be a relatively inert tissue, bone is actually quite dynamic and is constantly undergoing change. Some of that change, and particularly that which occurs in the long bones of the legs follows the principles of Wolf's Law that states bone changes to accommodate loads that are placed on it. In short, if less load is placed on the bone, it becomes weaker. If greater load is placed upon it, the bone becomes stronger. It has been suggested that this occurs as bone tries to maintain an "optimal strain environment". The long bones will bend, or experience strain, when they are loaded. This bending is very tiny and is measured in microstrain, but it provides an important signal to the bone. If the strain experienced is great, it signals that the bone is not strong enough and it needs to be strengthened. Conversely, if the strain is low, it signals that the bone is stronger than would typically be needed and mineral should be removed.

Though it might seem counterintuitive to make bone weaker, it is an important evolutionary advantage. Carrying around extra mineral in the legs results in an energetically unfavourable condition. It is noteworthy that there are no muscles in the equine lower leg as it is important to keep the legs, especially the distal portion, as lightweight as possible. If one considers the pendulum nature of the leg, this emphasis on keeping the leg lightweight can be easily understood. The lower the weight, the slower the pendulum moves. By having the muscle on a horse's leg located proximally, it allows the leg to move faster with less effort. The same applies to bone. As more bone mass is added, and as it is added distally, the more energy it takes to move the leg quickly. Thus, it is an evolutionary advantage to only have as much bone mass as needed to withstand the strain (bending) that would normally be encountered. While having bone strong enough to never break would seemingly be prudent, it would also slow down a prey animal making it more easily caught and eaten. Similarly, it would slow down a predator and put it at a disadvantage when it comes to catching prey. Thus, bone is constantly changing to accommodate forces it is likely to encounter but to remove any extra mineral that might not be needed.

6.2.1.2 Strain Versus Cycles

Recognizing that bone is influenced by bending, one can better understand how various training programs influence bone strength. Many horse people are under the belief that slow exercise conducted over long distances is useful for increasing skeletal strength. Often, the first few months of training involve lots of walking, trotting, and some slow cantering. While there can be many benefits of slow exercise, particularly for the mind of the horse, slow work has little benefit to the bone. Research clearly shows that bone responds to the magnitude of the load (with speed being one of the primary factors affecting load), as opposed to how many times the load is applied (cycles or strides). The force applied to bone influences the strain (or bending) and that is the signal for the bone to become weaker or stronger. With low-intensity work, the strain is low and thus the bone is not signalled to become stronger. With high-intensity work, such as that seen when sprinting, the strain is larger, and the bone is signalled to become stronger (or at least maintain its strength). Without high loads, again – typically achieved through sprinting, it is not possible to have high bone strength—regardless of how far a horse is trained at a slow speed.

Obviously, too many high-speed strides, particularly with a horse who has not been adapted to that type of exercise, can be detrimental. Like with a piece of wire that is repeatedly bent and experiences stress-hardening and eventually breaks, bone can be damaged by repeated bending and can eventually fail. However, unlike wire, the bone does have the capacity to repair itself if sufficient time is allowed. Further, bone can become stronger and more resistant to bending-related damage if properly trained and that is the ultimate goal of a training program.

6.2.1.3 Linear Versus Circular Exercise

It should be noted that, ideally, young horses should have limited circular exercise. If it has to be included in a training program, slow and large circles are less detrimental than fast and small circles. When travelling in a circle, whether in a round pen, on a lunge line, or on a racetrack, the faster the horse goes and the smaller the circle, the more uneven loading of joints that occurs as the loading force tends to focus on only a smaller aspect of the joint surface as opposed to being distributed evenly across the joint. Many well-being individuals, trying to introduce exercise to young horses, cause great harm to their animals by performing most of the exercise in circles, with resultant osteoarthritis or other joint damage being the result.

6.2.1.4 Housing

How a horse is housed can also influence the forces experienced by the skeleton. Numerous studies have reported a loss in bone mass of the third metacarpus when young horses are removed from pasture and placed into stalls—even when race training commences. Being walked daily on a mechanical walker fails to prevent bone loss from occurring. In yearling horses removed from pasture and put into stalls, bone mineral content of the third metacarpal had decreased after just 1 month of stalling and remained lower than pre-study values for close to 5 months, including the last 2 months of the study in which horses were put into training and ridden at the trot and slow canter. That study (conducted at Michigan State University in the late 1990s) was designed to be similar to what horses being prepared for sales might experience. Yearling horses often are stalled for preparation for sales with no access to either free or forced high-speed exercise, but instead are often just hand-walked. Then, after being purchased at auction, those horses continue to be stalled as they enter training which usually only encompasses slow exercise during the first couple of months. By the time speed is introduced, the strength of the skeleton is likely much weaker than it was before horses were ever put into stalls to begin being prepared for sales. Tragically, many of those horses then experience injury as they appear to be fit, but actually have the bone that is weakened due to lack of speed. Once speed is introduced to a horse that has lost bone mass due to stalling, injury is a high possibility unless a lot of time is taken to allow the bone to readjust to the higher strain rates associated with the reintroduction of sprinting.

6.2.1.5 Frequency and Length of Sprints

Several studies have documented that one daily sprint, as short as 50 meters, can prevent disuse-associated loss of bone in young, stall-housed animals of various species. Using juvenile bull calves in a terminal study, it was found that there were no differences in bone-breaking strength of the fused third/fourth metacarpi whether sprinted once, three times, or five times per week for 6 weeks. One single sprint per week of 71 meters, totally only 426 meters over a six-week period, produced a 25% increase in bone-breaking strength over calves not allowed to sprint at all. Applied for horses in training, this suggests that daily sprints are not necessary but providing a horse the opportunity to run at speed at least once per week is prudent to maintain bone strength. That does not mean there are no other benefits from more opportunities to sprint, but having at least some opportunity to stimulate the bone each week—whether while ridden or driven or while at liberty—is crucial to maintain bone health. In other animal species, the number of loading cycles (again, similar to fast strides) necessary to keep the bone strong has been shown to be quite low—possibly in the range of 4 to 20. For horses, that would suggest that possibly just five to ten seconds of running at speed may provide the necessary signalling to keep bone strong. However, it is not uncommon for horses in training to have no opportunity to sprint for months. When speed is reintroduced and when it is of rather long duration (24 to 36 seconds), it is not surprising that injuries occur. If there are no periods of disuse-associated bone loss, bone should be able to withstand the sprints of that duration without issue and length of speed work should be able to be progressively increase.

6.2.1.6 Bone Modelling Versus Remodelling

Many in the horse industry use the term bone remodelling to refer to all changes that occur within bone. Doing so is incorrect. Bone remodelling occurs throughout the life of an animal and refers to the replacement of old or damaged bone with new bone. Typically, bone remodelling results in little net change in the amount of bone present, little change in shape of the bone, and very little change in strength. Bone remodelling would be analogous to repairing potholes in a road. Damaged asphalt or concrete is removed and new asphalt is put into the pothole with the end-result being a road that is fixed, but not different in terms of size or strength than the original road.

Bone modelling is a term few horse people are familiar with but is an extremely important concept—particularly as it pertains to a growing horse. Bone modelling occurs primarily during the period of long bone growth and is the process by which bone can change shape, can add or subtract bone, and increase or decrease strength. Given bone modelling is most active during growth of an animal, this is the time during which the greatest chance for increasing strength can take place. Comparing it to road construction, the easiest time to determine the size of the road (for example, whether it is a small two-lane country road versus a six-lane highway) is when the road is being built. This is also the easiest time to alter the thickness of the road and the shape or curvature of it. Likewise, the best time to make bone stronger is during the period in which bone modelling is occurring.

It is easy to comprehend how making the bone bigger and adding more mineral will make it stronger. However, the shape can also influence how resistant the bone is to bending. If one were to take a cardboard tube and squeeze it slightly, it will become more oval and less round. In the direction in which the tube has greater width, it is more resistant to bending. In the direction in which the tube is narrower, it is less resistant to bending. Even though the amount of cardboard never changed, the shape of the tube influenced the moment of inertia. Thus, the changes that occur with bone modelling (changes in shape and altering how big the bone is and how much mineral it contains) are all critical to making the bone stronger and more resistant to injury. And these changes primarily happen when the animal is actively growing. Once the animal is skeletally mature, changes to the skeleton primarily occur through bone remodelling which, once again, tends to just replace old or damaged bone.

6.2.1.7 Commencement of Training Relative to the Closure of Growth Plates

It is a common belief among horse people that one should wait until the knees of a horse are “closed” to begin training to decrease the likelihood of injury. When referring to knees being “open” or “closed”, this pertains to the closure of the epiphysial plates (see Chap. 2). The belief is that when this occurs and the knees are “closed”, the horse has reached a state of maturity at which point one can more safely train the horse with decreased injury risks.

Despite this widespread belief, research does not provide support for this practice. An Australian study published in the early 1970s, examined the injury rates in two-year-old Thoroughbreds in race training and compared them to the closure of the distal radial epiphysis. Horses were categorized as having knees “open”, “closed”, or “intermediate” at the time training commenced. The study found that 77% of horse that started training with open epiphyseal plates remained sound throughout the study but only 55–56% of those who started training when their knees were “closed” or “intermediate” remained sound. While such findings might have been attributed to horses with “open knees” being trained or raced less rigorously, the authors stated that many horses with open epiphyses raced six or more times and remained sound while numerous horses with closed epiphyses became unsound before their first race or before completing six races. Additionally, the researchers reported horses with closed epiphyses showed greater incidence of lameness and poor performance.

For those who understand the difference between bone modelling and remodelling, the results of this study are not surprising. To make bone stronger, bone modelling needs to occur and that primarily takes place during long bone growth. Once the horse is finished growing, only bone remodelling can occur to repair damage—but not to strengthen bone. Hence, waiting to start training until a horse has “closed knees” is actually detrimental to maximizing skeletal strength.

Convincing individuals that training horses while they are young and growing is beneficial can be challenging, especially if they are not familiar with the concept of bone modelling. Further, most who believe that waiting until they are skeletally mature also believe it is crucial for the horse’s welfare. Even the authors of the Australian study did not believe their own results and attempted to justify their findings that were in contrast with common belief. The authors suggested that the horses with early closure of epiphyses may have had some nutritional factor that caused a “generalized skeletal dystrophy”. Like with young horses, it is recommended that children participate in high-cyclic repetition activities to benefit bone and joint health. Inactivity has been shown to be harmful to the health of epiphyseal growth plates. Having children play in sports shows obvious benefits and rarely would one suggest waiting until a human is skeletally mature before starting athletic training. While nutritional factors can certainly play a role in skeletal health, the importance of exercise in producing strong bone cannot be overemphasized, particularly in the growing horse.

6.2.2 Nutritional Factors

Proper nutrition of the growing horse is critical. While nutritional needs and feeding management of the growing horse is covered in Chap. 3, there are several items that directly relate to proper growth and development of the skeletal system which need to be emphasized.

6.2.2.1 Nutrient Ratios

It has long been recognized that it is important to have more available calcium in the diet, relative to phosphorus, to prevent Nutritional Secondary Hyperparathyroidism and subsequent skeletal issues. While a 2:1 calcium to phosphorus ratio is often recommended, that precise ratio is not required. It has been shown that horses tolerate a fairly wide range of calcium to phosphorus ratios and any ratio between 1.1:1 and 6:1 should be considered safe for a growing horse, as long as there are not such things as dietary oxalates (found in some tropical forages) that interfere with calcium absorption. Likewise, while some have suggested very precise ratios of various minerals (such as zinc to copper), this has yet to be confirmed by research. The 2007 Horse NRC provides the minimum amounts required of various minerals, but that does not automatically translate to being a required ratio. Trying to ensure precise ratios of many nutrients would be challenging from a practical standpoint and a need to do so has not been documented.

A more important consideration for the growing horse may be the nutrient to calorie ratio. By taking into consideration the required amounts of required nutrients (such as protein/amino acids and minerals such as calcium) and comparing those required amounts to the amount of energy required, it is possible to make sure that neither an excess of energy nor a deficiency in nutrients is present. Excess dietary energy without a relative increase in other dietary nutrients likely would result in horses prone to excessive weight gain in the form of body fat without the more desired growth of lean body mass. One study reported yearlings fed similar energy but less protein, calcium, and phosphorus had the same weight gain as horses fed an appropriate nutrient: calorie ratio but the horses fed a low nutrient to calorie ratio diet were shorter at the withers and had a two-fold greater rump fat thickness. Thus, those people feeding growing horses would be prudent to evaluate the nutrient to calorie ratios of the diets their horses are receiving and compare them to the ratios that would be expected when fed the amounts recommended by the NRC (2007). The only requirement for which it is possible to know whether the amount being provided is appropriate is energy as one can body condition score their horse to know whether energy intake is adequate and appropriate. However, that still does not guarantee the ratio of energy to nutrients is appropriate as a horse could have an appropriate body condition score but could be not consuming enough other nutrients necessary to support healthy growth of the skeletal system.

6.2.2.2 Analysis of the Feed Composition

It is critical to know the nutrient content of feeds provided to horses to know whether requirements are being met. The only way this can be done is to have the feedstuffs analysed, as highlighted in the chapters of this book dealing with nutrient requirements and feeding management. While most commercial feedstuffs such as grain mixes provide a guaranteed analysis of their nutrient content, typically such feeds constitute the minority portion of the diet of all types of horses. Roughages, however typically, make up the majority of what a horse consumes, thus knowing what nutrients are being provided by the roughages is necessary. Many forages may be deficient in some critical minerals and don't meet all of the micronutrient requirements of growing horses but, and only by analysing the feed, it is possible to know what may be deficient. For example, insufficient Cu content can be detrimental to bone health, particularly if a horse is genetically predisposed to develop bone-related problems.

6.2.2.3 Exercise Versus Nutrition

There is a general belief amongst many that providing various supplements can improve bone health. As mentioned above, any nutrient deficiencies should be corrected to prevent problems from developing. However, it is wrong to believe that nutrition, by itself, can make strong bone. Many nutritional studies have evaluated markers of bone metabolism to look for differences in response due to diet. As long as deficiencies are not present, few of these studies have detected changes in these markers due to variations in diet. By contrast, when used to evaluate variation in training programs, exercise, or management systems, many studies have shown changes in the bone markers.

One could incorrectly interpret that to mean that nutrition is not important for making strong bone. It is crucial to feed young horses a balanced diet in which dietary needs are being met. But just providing good nutrition will not optimize bone health if the correct exercise is not being afforded to horses. Given that bone responds to loading, not providing sufficient or correct stimuli for the bone to become stronger will result in weak bone—regardless of what the horse is fed.

6.2.3 Role of Genetics

Certain bone and cartilage-related problems, such as those categorized as developmental orthopaedic diseases (DOD), have been linked to genetics. In particular, osteochondrosis has been shown to have a genetic component. Despite genetics being established once a horse is conceived, proper nutrition and management of exercise and housing can decrease the chance of a horse being afflicted with associated soundness issues. Improper amounts of minerals, combined with excess energy or carbohydrates have been implicated in the development and severity of DOD and, combined with a genetic propensity for such, may increase the chance of affliction. As discussed prior, maintaining a young horse in a box stall without access to free exercise can be detrimental to development of the musculoskeletal system and is ill-advised, particularly for young horses genetically prone to osteochondrosis. During the first part of life, while the horse is rapidly growing, the musculoskeletal system is susceptible to negative influences and, in particular, the lack of loading associated with stall rest. Thus, proper exercise, along with a balanced diet, are important tools in combatting genetically-associated bone problems.

Key Points

- The best opportunity to make the skeleton strong is to provide it proper stimuli through exercise when a horse is young and growing. Once a horse is skeletally mature, changes in bone primarily are to repair old or damaged bone, as opposed to making it stronger.
- Maintaining skeletal strength is one advantage resulting from housing a young horse on pasture and large paddocks.
- A horse that trots for many kilometres will have the bone that has been trained to accommodate only loads associated with low speeds and would face the risk of injury if excess strides at speed are suddenly introduced.
- By contrast, a horse that sprints a few dozen metres will have the bone trained to accommodate loads associated with high speeds. If allowed to run at top speed on their own, bone strength can be maintained simply through turn-out—even if only once or twice a week.
- Proper nutrition is vital for a healthy skeleton, if the proper exercise is accompanying it. It is impossible to have a strong skeleton if the bone is not stimulated to become strong through the right type of exercise.
- Many problems associated with bone health can be avoided by providing a balanced diet and ensuring the skeletal system is trained properly. Such training involves stimulating the bone to be strong through short sprints (which is often done by young horses on their own if allowed to do so) and by avoiding damaging joints through excessive circular exercise which unevenly loads the joints.

6.3 Parasite Control of the Foal and Young Horse (Eva Tyden, Frida Martin, Ylva Hedberg-Alm)

Foals and young horses are particularly susceptible to parasitic infection, as they have yet to develop immunity to the parasites. In addition, young horses excrete larger amounts of parasitic eggs compared to their mature counterparts, and substantially contribute to parasite infectivity in the environment. In contrast to feral horses, domesticated equines are confined to limited grazing areas, and are thus exposed to higher parasite infection pressures. However, because anthelmintic resistance has developed in several equine parasites, reliance on anthelmintic treatments alone is not sustainable, in particular since no new anthelmintic drugs are expected to be available on the market in the foreseeable future. Thus, in foals and young horses, in addition to strategic anthelmintic treatment, at times without prior diagnostics, management practices aiming to reduce parasite burdens on pastures are especially prudent. The following part of this chapter will discuss the equine

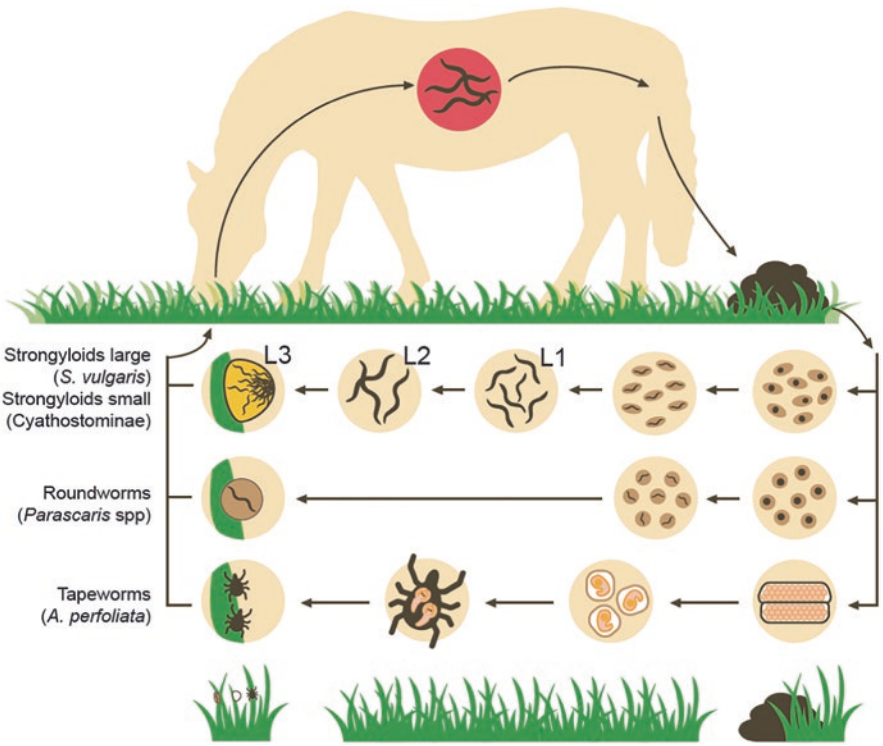

Fig. 6.1 The schematic picture illustrates the transmission of the most common pasture-born parasites of horses. Illustrator Cajsa Lithell

internal parasites of particular importance to the health of foals and young horses, as well as preventative and treatment measures that help minimize the risk of parasitic disease (Fig. 6.1).

6.3.1 Parasites of Foals and Young Horses

6.3.1.1 *Cyathostominae* (Small Strongyles)

Cyathostominae are the most common equine internal parasites and infect horses of all ages. More than 50 different species belong to the Cyathostominae family. Adult parasites are 0.5–1.5 cm in length and range in colour from white to dark red.

6.3.1.2 Life Cycle

Cyathostominae have a direct life cycle without tissue migration. Eggs in the faeces are deposited on the ground, where they hatch and develop to the infective larval stage (L3). Although development on average takes about 2–4 weeks, there is a direct relationship between the rate of development and temperature, with eggs able to yield L3 in as little as three days under optimal conditions (25–30 °C). Facilitated by moisture, L3 migrate from the faecal pats to the herbage enabling infection of the grazing horse. After ingestion, the L3 encapsulates in the mucosa of the large colon and cecum, where development to L4 occurs. The L4 thereafter return to the intestinal lumen and finally develop into egg-producing adult worms. The entire life cycle takes approximately 2–3 months. However, particularly during the autumn and winter months, the early L3 can enter a hypobiotic stage with arrested development for several months up to two years. This seasonally induced arrested development is likely due to environmental factors, such as temperature and photoperiod. A successive return to larval development during the spring ensures egg production when conditions for larval development on the pasture are optimal.

6.3.1.3 Prevalence: Epidemiology

Cyathostominae are considered ubiquitous in grazing horses, with a prevalence of up to 100% reported in many regions of the world. Young horses generally excrete larger number of eggs in their faeces compared to more mature horses and foals. In the majority of healthy mature horses, the degree of egg shedding is consistent over time, and as a general rule, it is accepted that approximately 20% of horses are responsible for 80% of pasture contamination.

6.3.1.4 Pathogenesis and Clinical Signs

The association between Cyathostominae and colic has yet to be established and case-control studies have failed to demonstrate a clear connection. Young horses, often less than 5 years of age, can, however, develop severe diarrhoea if large amounts of hypobiotic larvae re-emerge simultaneously, a condition known as larval cyathostomiasis. The condition often occurs in late winter/early spring and can be fatal. In addition, large parasite burdens have been reported to cause signs of chronic clinical disease, such as weight loss, loose faeces, and a dull hair coat. The risk of clinical disease due to large burdens of Cyathostominae is likely to be strongly associated with the individual's general nutrient status and overall health.

6.3.1.5 *Strongylus Vulgaris* (Large Strongyles)

There are three primary species of large strongyles, *Strongylus vulgaris*, *Strongylus endentatus*, and *Strongylus equinus*, that infect the horse of which *S. vulgaris* is the most prevalent and considered to be the most pathogenic equine intestinal parasite. Adult *S. vulgaris* are dark red in colour, approximately 2.5 cm in length, and infect horses of all ages.

6.3.1.6 Life Cycle

The initial life cycle is identical to that of Cyathostominae, but extensive larval migration within the vasculature of the horse results in a prolonged prepatent period of approximately 6–7 months. After ingestion of the L3 stage, development to L4 occurs in the submucosa of the large colon, whereby the larvae begin to migrate through small arterial vessels, reaching the cranial mesenteric artery and its major branches after about 2–3 weeks. Approximately, 90 days post-infection, the L4 moult to young L5, that return via the arteries to the ventral colon and cecum, where they form small nodules in the submucosa. After rupture of the nodules, releasing the young adult worms into the intestinal lumen, maturation over a 6–8-week period into egg-producing worms occurs.

6.3.1.7 Prevalence: Epidemiology

Before the widespread use of modern anthelmintic drugs, the prevalence of *S. vulgaris* was reported to be above 80%. Thereafter, regular interval anthelmintic dosing regimens led to a substantial decline in prevalence. The indiscriminate use of anthelmintic treatment of all horses, however, has resulted in anthelmintic resistance in other nematode species, primarily Cyathostominae and *Parascaris* spp. As a result, selective anthelmintic treatment is now advocated in many parts of the world, and some countries (e.g. Denmark and Sweden) have subsequently seen a rise in *S. vulgaris* prevalence, with reported prevalence rates of between 12 and 28% at an individual level and between 61 and 64% at farm level.

6.3.1.8 Pathogenesis and Clinical Signs

The larval migration of L4 in the cranial mesenteric artery and its branches causes a marked inflammation, resulting in thickening of the arterial walls and infiltration of inflammatory cells. One to four months post-infection, thrombosis formation occurs, and detachment of thrombotic material can lead to occlusion of smaller arteries, compromising perfusion of the intestinal wall. The result is a thromboembolic colic with intestinal infarction and subsequent septic peritonitis. Affected horses show varying degrees of colic accompanied by signs of systemic inflammation, such as fever and elevated inflammatory markers in the blood (Fig. 6.2).

6.3.1.9 *Parascaris* Spp.

The equine roundworm *Parascaris* spp. mainly infects foals. The adult worms measure 15–50 cm with a whitish colour. This parasite has traditionally been referred to as *Parascaris equorum*, but recent studies suggest that the related *Parascaris univalens* is now the dominating species.

6.3.1.10 Life Cycle

Parascaris spp. have a direct lifecycle, but unlike strongyle parasites, the eggs do not hatch outside the horse. Instead, the foals ingest eggs containing infective larvae from the environment. The eggs hatch in the small intestine and the larvae penetrate the intestinal wall. The larvae then migrate through the liver, lungs, and airways to the pharynx where they are swallowed and end up in the small intestine within 3 weeks after infection. Here the larvae mature to adult worms, 15–50 cm in length, which reproduce. Egg shedding starts 10–15 weeks after infection and the female worms release large numbers of eggs that are passed with the faeces. Heavily infected foals can shed millions of *Parascaris* spp. eggs every day, and infective larvae develop within two weeks in favourable conditions. The infective eggs are resistant to weather conditions and survive for more than 18 months in the environment, ready to infect the next generation of foals.

Fig. 6.2 Injuries caused by *S. vulgaris*. An acute non-strangulating intestinal infarction in the left ventral colon caused by migrating larvae in the cranial mesenteric artery and its branches. Photo Ove Wattle Lithell

6.3.1.11 Prevalence: Epidemiology

Most foals are exposed to *Parascaris* spp. infection during their first days of life, and prevalence of up to 83% have been reported. Foals around 6 months old develop immunity to the parasite and infection of adult horses is therefore uncommon.

6.3.1.12 Pathogenesis and Clinical Signs

Parascaris spp. are considered to be the most pathogenic parasites for foals. Clinical signs of infection may include mild respiratory symptoms such as coughing and bilateral nasal discharge due to larval migration in the lungs. Signs such as lethargy, weight loss, and impaired growth are suggested to be caused by adult worms competing for space and nutrients in the small intestine. In severe cases, large worm burdens in the small intestine can cause impaction and even rupture of the intestinal wall, which may be lethal (Fig. 6.3).

6.3.1.13 Strongyloides Westeri

Strongyloides westeri is a small worm (<1 cm × 1 mm) infecting foals during the first months of life.

6.3.1.14 Life Cycle

Strongyloides westeri has a complex life cycle, alternating between a parasitic and a free-living phase, where only the females are parasitic. L3 may infect adult horses

Fig. 6.3 *P. univalens*. Large worm burdens in the small intestine can cause impaction and even rupture of the intestinal wall. Photo Elin Svonni

by penetrating the skin or mucous membranes followed by migration to somatic tissues where further development is arrested. In pregnant mares, hormones stimulate arrested L3 to migrate to the mammary glands. Foals become infected by two routes: (i) through ingestion of L3 in the mare's milk, which is the primary route, or (ii) through the environment via either oral ingestion of L3 or L3 penetration of the skin. Within the foal, L3 undergo pulmonary migration and return to the proximal small intestine, where they develop to adult female worms and start to produce eggs. The prepatent period of *S. westeri* is usually 10–14 days. Eggs are passed out with the faeces and hatch to become either free-living males, females, or infective parasitic L3. Most foals develop permanent immunity to *S. westeri* by 5–6 months of age.

6.3.1.15 Prevalence: Epidemiology

Historically, the prevalence of *S. westeri* was approximately 90%, but has dramatically decreased after the entrance of anthelmintic drugs. Surveys conducted in late 1990 to early 2000 reported prevalences of 1.5–6% and thereafter an increase to 15–30% in later studies, conducted after 2010.

6.3.1.16 Pathogenesis and Clinical Signs

Strongyloides westeri is a rare cause of disease, but there are cases associated with enteritis and diarrhoea in foals with heavy infection. Massive percutaneous penetration of L3 through the skin can cause skin irritation with hyperactivity and extreme discomfort ("frenzy").

6.3.1.17 Tapeworms

There are three species of tapeworms (cestodes) that infect horses, and, of these, *Anoplocephala perfoliata* is the most prevalent and frequently associated with clinical disease. Adult *A. perfoliata* are usually 25–40 mm in length with a width of 8–14 mm.

6.3.1.18 Life Cycle

Anoplocephala perfoliata has an indirect life cycle dependent on a free-living mite (Oribatidae). On the pasture, the mites ingest eggs of *A. perfoliata* from the horse's faeces. Within the mite, the larva or oncosphere is released from the eggshell and further develops to the infective stage, known as a cysticercoid. This process usually takes 8 to 20 weeks. Horses are infected via ingestion of the mite while grazing. The excysted larvae of *A. perfoliata* move along the gastrointestinal tract with the ingesta to the ileocecal valve area, where the larvae attach to the intestinal mucosa and develop into adult worms that produce proglottids (segments containing eggs). The proglottids of *A. perfoliata* are broken up by digestion during transit and only eggs are passed in the faeces. The prepatent period following ingestion of an infected oribatid mite is 6 to 16 weeks.

6.3.1.19 Prevalence: Epidemiology

Tapeworms infect horses of all ages, and infection has been observed in foals from 5 months of age. The prevalence of *A. perfoliata* has been reported to be lower in horses younger than 1 year (30%) compared to adult horses (52–60%). Worldwide, the prevalence varies between 13 and 80%.

No actual data are available on the life span of adult *A. perfoliata*, but presumably, this varies from a few months to several years. Mites containing cysticercoids can persist in the environment for 1–1 1/2 years.

6.3.1.20 Pathogenesis and Clinical Signs

Infection with *A. perfoliata* can cause colic due to lesions in the intestinal lining of the ileocecal junction or cecum. The parasite has also been associated with recurrent episodes of spasmodic colic.

6.3.2 Diagnosis

Even though all horses harbour parasites to some extent, it is important to determine which species the horse is infected with and, in some cases, the level of egg shedding, as this will influence the choice of anthelmintic treatment.

The most common way to diagnose parasitic infection is by detecting parasite eggs in the faeces. It should, however, be noted that in order to detect parasite eggs in the faeces, a patent infection, i.e. the presence of adult parasites shedding eggs, is required. Therefore, horses may have clinical disease caused by parasite larvae even though there are no parasite eggs detected at coprological examination. All parasites presented above may be diagnosed by flotation techniques, where faeces are dissolved in a flotation media with higher specific gravity than the eggs. The eggs then float to the top of an examination chamber and can be counted using a low magnification in a light microscope. If specified volumes of faeces and flotation media are used and a specific volume is examined, the number of eggs per gram of faeces (EPG) can be determined. This faecal egg count is often used to decide whether the horse needs parasite treatment. Due to intermittent excretion of eggs containing proglottoids, a modified centrifugation/flotation technique is needed to diagnose *A. perfoliata* from faecal samples.

The faecal egg count is often used to determine whether the horse needs parasite treatment. It should, however, be noted that in order to detect parasite eggs in the faeces, a patent infection, i.e. the presence of adult reproducing parasites in the intestine, is required. This means that EPG does not correspond to the worm burden and that horses may have clinical disease caused by parasite larvae even though there are no parasite eggs detected at coprological examination.

Since it is not possible to distinguish between eggs from small and large strongyles, additional examinations are necessary. The presence of large strongyles such as *S. vulgaris* can be confirmed by microscopic examination of L3 after culturing the faeces for 2 weeks, allowing the eggs to hatch and L3 to develop. In addition, there is a real-time PCR technique that can detect *S. vulgaris* eggs in the faeces at high sensitivity. It should be noted that due to the long pre-patency period of *S. vulgaris*, eggs may only be detected if more than 6 months have passed since the previous deworming.

Due to intermittent excretion of eggs containing proglottids, a modified centrifugation/flotation technique is needed to diagnose *A. perfoliata* from faecal samples. In addition, there are commercial ELISA assays available to identify tapeworm infection by detecting tapeworm-specific antibodies in horse serum or saliva. However, since antibodies may persist for several weeks to months after treatment, there is a risk of false positive results. Serological methods are therefore suggested to be of better use to determine overall exposure at the farm than current infection of individual horses.

6.3.3 Resistance

Anthelmintic resistance means that parasites have acquired the ability to survive drug treatment at a dose that would normally be lethal. This ability is due to changes in the genome of the parasite that are advantageous for survival under the selection pressure of drugs. Once resistance has established, it is usually non-reversible.

Resistance has been reported in both *Parascaris* spp. and Cyathostominae. *Parascaris* spp. resistance to macrocyclic lactones are considered to be widespread across the world. In addition, there have been several reports of *Parascaris* spp. resistance to pyrantel and single reports of resistance to fenbendazole. In Cyathostominae, resistance to both benzimidazoles and pyrantel is common worldwide. There have also been reports of reduced efficacy of macrocyclic lactones, as well as shortened egg reappearance times, an early sign of resistance, after treatment.

There are currently no available methods to determine the efficacy of anthelmintic drugs against *A. perfoliata* in horses, although single cases of suspected treatment failure to pyrantel have been described. No cases of anthelmintic resistance have so far been reported in either *S. westeri* or *S. vulgaris*.

The best practice to evaluate anthelmintic efficacy on the farm is to perform a faecal egg count reduction test (FECRT), where the faecal egg count is determined before and 10–14 days after treatment. If the drug is fully effective, no parasite eggs should be present after treatment. It is recommended to do yearly FECRT on farms to ensure that an effective treatment is used.

6.3.4 Treatment and Monitoring

Due to their high susceptibility to parasitic disease, anthelmintic treatment in foals, and sometimes youngsters, is advisable without prior diagnostics. In older youngstock, faecal monitoring and treatment only if EPG exceeds a pre-determined cut-off value, often 200–500 EPG, is recommended. Whenever large strongyles or tapeworms are diagnosed, however, treatment should be performed regardless of EPG levels. A summary of the currently available published guidelines for the treatment and monitoring of relevant parasites is shown in Table 6.1.

6.3.4.1 Foals

S. westeri is not a common pathogen, and treatment should be reserved to cases with clinical signs, such as enteritis, with confirmed presence of the parasite using faecal diagnostics. Foals and yearlings, especially in larger groups and at stud farms, are, however, highly likely to become infected with *Parascaris* spp. In general, most guidelines specify at least two, sometimes three, treatments for *Parascaris*, at 2–3-month intervals, from the age of 2 months. Due to anthelmintic treatment showing lower efficacy towards the larval stages, treatment of foals younger than 60 days is not advisable. An additional treatment of yearlings, depending on the results of faecal diagnostics, may be warranted in late winter/early spring. Because of widespread resistance to macrocyclic lactones, and reports of resistance also to pyrantel, benzimidazole is the drug of choice. Grazing foals are also exposed to Cyathostominae and tapeworms and will require treatment for these parasites during the autumn. This treatment can be done with or without prior diagnostics, depending on the number of foals on the farm and any historic presence of tapeworms. Since widespread resistance to benzimidazole occurs in Cyathostominae, with reported resistance to pyrantel, the drug of choice will be macrocyclic lactones, unless documented efficacy to pyrantel has been demonstrated on the farm. A faecal sample in the autumn can be used to direct drug choice prior to treatment. Praziquantel is the drug with highest efficacy against tapeworms; however, this drug is, in most countries, only available in combination with a macrocyclic lactone. Pyrantel at a dosage

Table 6.1 Summary of currently available published guidelines for anthelmintic treatment and monitoring of foals and young horses (≤4 years of age)

Parasite	Time point of treatment	Monitoring	Drug class	Resistance	Remarks
S. Westeri	ESCCAP[a]: Foals approx. 4 weeks old	Treatment only if *S. Westeri* is found on the farm	BZ[d] or ML[e]		ESCCAP, AAEP: Treatment of mares prior to foaling is not recommended.
Parascaris spp.	ESCCAP[a]: At 2, 5, and 8 months. At 11–12 months if detected UK.Vet.Eq[b]: At 3, 5 months, and at 7–8 months if detected AAEP[c]: At 2–3, 4–6 months, and at weaning if detected	ESCCAP[a]: Monitoring prior any treatment after 3 months of age UK vet. Eq[b]. And AAEP: Autumn/at 7–8 months	BZ[d]	Worldwide resistance to ML Occasional reports to PYR Single reports to BZ	
Cyathostominae	ESCCAP[a]: 2, 5, and 8 months. At 11–12 months only if required (EPG). Thereafter 3 treatments (all horses up to 4 years) starting 1–2 months post-turnout, at 2–3 month intervals UK.Vet.Eq[b]: Larvicidal treatment at 7–8 months/autumn, if grazing over winter again after 3 months (MOX). Thereafter possibly every 8–12 weeks during grazing season, based on EPG AAEP[c]: At weaning, 9, 12 months, thereafter 3–4/year, depending on farm management Treatment with MOX/PZQ 1–2 times/year (autumn, and 3 months later if grazing throughout the winter)	ESCCAP[a]: Monitoring prior any treatment after 3 months of age UK.Vet.Eq[b]: In youngsters, faecal samples 3 times during the grazing season (spring, June/July, autumn) AAEP[c]: Faecal sample prior treatment only in horses >3 years of age	ML[e] UK. Eq. vet: Larvicidal treatment: MOX[f] in autumn, and again after 3 months if grazing over winter	Worldwide resistance to BZ Occasional reports to PYR Single reports to ML	

S. vulgaris	ESCCAP[a]: At housing (Nov/Dec) (ML) UK.Vet.Eq[b]: 1–2/year (autumn, possibly 3 months later if grazing over winter), without prior diagnostics (larvicidal treatment, MOX)	Faecal examination in the spring (April/may), Culture/PCR	BZ[d], PYR[g], ML[e]		When positive culture/PCR, treat all horses sharing pasture.
A. Perfoliata	ESCCAP[a]: Single annual treatment in Nov/Dec, additional treatment Aug/Sep if high infection rate UK.Vet.Eq[b]: Treatment in autumn if needed (serology) AAEP[c]: Treatment in late autumn/early winter	Faecal examination (special technique) or serology (saliva/serum) 1–2/year (autumn best time for antibody testing)	PZQ[h] PYR[g], twice labelled dose		

[a]*ESCCAP* GL8: A Guide to the Treatment and Control of Equine Gastrointestinal Parasite Infections; [b]*UK-Vet Equine* Equine de-worming: a consensus on current best practice; [c]*AAEP* Internal Parasite Control Guidelines; [d]*BZ* benzimidazole; [e]*ML* macrocyclic lactone; [f]*MOX* moxidectin; [g]*PYR* pyrantel; [h]*PZQ* praziquantel

twice that of the labelled dose does have efficacy against adult tapeworms. The presence of tapeworms can be assessed by faecal samples, from the age of 3 months, or by detection of antibodies, from the age of 5 months.

6.3.4.2 Youngsters (1–3 Years Old)

Young horses will in general excrete larger amounts of strongyle eggs compared to their mature counterparts and thus contribute substantially to contamination of the pasture. Treatment for Cyathostominae should be based on regular faecal monitoring throughout the grazing season, for example in the spring prior to turn-out, and during the mid- and late grazing season, depending on the climate and grazing facilities. Horses exposed to long grazing seasons, or in regions where grazing is provided throughout the winter, may require additional monitoring and treatments. As the parasitic infection pressure in general culminates in the autumn, it is highly recommended to move horses to a new grazing area at this time, with faecal monitoring and anthelmintic treatments as required, prior to moving.

It is important to include annual diagnostics for large strongyles, using culture or PCR techniques, and due to the parasite's long pre-patent period of around 6 months, such diagnostics are preferably performed in the spring, prior to turn-out. Some guidelines suggest routine treatment 1–2 times per year with a macrocyclic lactone, regardless of prior diagnostics, to address any large strongyles present. In addition, tapeworm diagnostics (serology or faecal samples) should be employed annually or bi-annually. If the farm has a history of documented tapeworm infection, an annual tapeworm treatment in the autumn of all youngstock should be considered. Stocking rates, pasture management practices, and time at pasture are all factors that influence the overall parasitic burden.

6.3.5 Other Management Systems and Regrouping

Modern management practices, such as open stable systems, where youngsters are kept outdoors in herds throughout the year, will still require regular individual faecal monitoring. If individual sampling is prohibitive, however, pooled samples of a maximum of five horses can be used in exceptional instances. Such sampling will be less sensitive for the detection of *S vulgaris* and does not account for individual egg excretion rates, potentially leading to an increase in the number of anthelmintic treatments given.

Any move to a new group, for example after weaning, should be performed only after anthelmintic treatment. Ideally, a faecal sample should be taken 14 days post-treatment and prior to turn-out in the new group, to ensure anthelmintic efficacy.

6.3.6 Pasture Management

In order to avoid sole reliance on anthelmintic drugs, which due to emerging resistance is unadvisable, management practices to reduce the parasitic burden on pastures are required in conjunction with a monitoring and treatment programme.

Faecal removal twice weekly has been shown to be more effective than anthelmintic treatment and should be employed throughout the grazing season. Since larval development can occur at temperatures as low as 4 °C, although at a lower rate, it is advisable to practice faecal removal from any paddocks in use, as long as temperatures are above freezing. In addition, overwintering parasite eggs will hatch and develop in the spring, in response to increasing temperatures together with rainfall.

Co-grazing or rotational grazing with other animal species, such as sheep or cattle, is another management practice that can help to reduce infection pressures, since the parasites are species-specific and will not infect non-equids. High stocking densities should be avoided, particularly in young horses, with factors such as the quality of the pasture and the total number of grazing animals influencing which stocking rates can be tolerated. As a guideline, 0.4–1.2 hectare per horse in temperate climates is suggested.

Since foals and young horses are vulnerable to parasitic disease, and with young horses contributing the most to pasture contamination, owing to their generally high egg excretion, permanent year-round pastures or paddocks should be avoided in these age groups. If permanent pastures are to be used, pasture management practices such as year-round faecal removal and low stocking rates are paramount. Ideally, the paddocks should be sectioned, allowing for parts of the paddock to rest, with one section grazed at a time. Rotational grazing of groups of horses on a monthly basis has been shown to reduce parasite infection rates.

Other methods to lower infection pressures include using the fields to harvest hay or deep-ploughing followed by re-seeding. Eggs of the equine roundworm, however, may survive deep-ploughing, with this practice resulting only in a temporary benefit, since viable eggs may return to the surface when the field is ploughed a second time.

Spreading non-composted manure or harrowing are practices that should be avoided. Harrowing effectively spreads parasite larvae over the pasture, rendering horses unable to use their natural instinct to avoid grazing rough areas containing their faeces, and has been shown to increase parasite burdens in foals. In addition, it is advisable to keep dung heaps separate from grazing areas.

6.3.7 Climatic Factors

Although no larval development appears to occur below 4 °C, L3 are not very susceptible to cold and survive longer at low temperatures (−5 °C and 3 °C) compared to high temperatures (26 °C and 31 °C). Therefore, while resting pastures in hot and dry climates can be beneficial in reducing parasite burdens, but since strongyle larvae can overwinter, resting pastures over the winter season is of minor benefit. Alternation between frost and thaw, however, has deleterious effects on most stages of strongyles. Thus, the climatic conditions will influence parasitic burdens and should be taken into consideration when designing a pasture management plan.

Key Points

- Young horses excrete larger amounts of parasitic eggs compared to their mature counterparts and substantially contribute to parasite infectivity in the environment.
- It is important to determine which species the horse is infected with and, in some cases, the level of egg shedding, as this will influence the choice of anthelmintic treatment. The most common way to diagnose parasitic infection is by detecting parasite eggs in the faeces.
- Due to their high susceptibility to parasitic disease, anthelmintic treatment in foals, and sometimes youngsters, is advisable without prior diagnostics. Regular monitoring for large strongyles in youngsters (1–3-year-olds) is recommended.
- Open stable systems, where youngsters are kept outdoors in herds throughout the year, will still require regular individual faecal monitoring. Any move to a new group, for example after weaning, should be performed only after anthelmintic treatment.
- Faecal removal twice weekly has been shown to be more effective than anthelmintic treatment and should be employed throughout the grazing season. It is advisable to practice faecal removal from any paddocks in use, as long as temperatures are above freezing.
- High stocking densities should be avoided, particularly in young horses. As a guideline, 0.4–1.2 hectare per horse in temperate climates is suggested.
- Parasites may have acquired the ability to survive drug treatment at a dose that would normally be lethal. This ability called anthelmintic resistance is due to changes in the genome of the parasite that are advantageous for survival under the selection pressure of drugs. Once resistance has established, it is usually non-reversible.

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