Factors affecting Bone Health in Horses

Dr C.E. Foote

Musculoskeletal injuries are the most common cause of poor performance and wastage in the equine industry. This article reviews some of the literature describing the effect of nutrition and exercise on bone strength and development.

Summary:

- The bone mineral content (which is a measure of the amount of mineral in a bone) is an important determinant of bone strength during the development phase of an animal's life. Two of the most important factors thought to have an important bearing on the bone mineral content, and therefore bone strength are exercise and nutrition.
- Exercise training should stimulate bone modeling, improve skeletal strength and in theory reduce the probability of exercise associated skeletal injuries.
- Confining horses to stables may also affect bone strength, with studies describing decreases in bone mineral content in horses kept stabled.
- Long breaks from training either voluntarily or forced by an injury will lead to a decrease in bone mass and strength. The longer the spell, the more gradual the increase in the volume and intensity needed to minimise the risk of excessive strain on bone.
- Studies indicate that confinement of foals up to five months of age may result in retardation of normal development.
- Supplemental calcium (above current recommendations) has been shown to improve bone mineral density in horses in training. Supplementation of calcium has not been shown to be effective in preventing a decrease in bone mineral content during deconditioning or resting. It is therefore the combination of calcium supplementation and exercise that is important in improving bone mineral density.
- Other factors which affect bone strength may include growth, gender, aging, genetics, infection and immunity, hormones and cytokines.

Studies indicate that through strategic nutritional manipulations and management practices, it may be possible to increase or preserve bone mass and to maintain bone strength.

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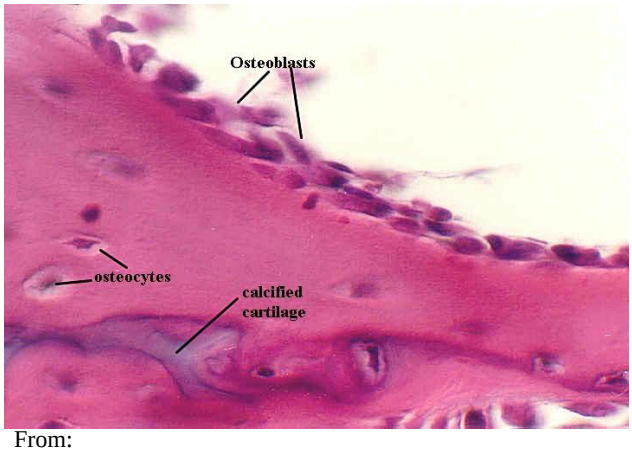
Bone - structure and function

Bone is a dynamic tissue that is constantly undergoing change in an attempt to maximise its strength in the face of changing demands. The basic structure of the bone includes three types of cells and an extracellular matrix which is the material that resides outside the cells and gives bone its overall strength.

The three cell types are:

- Osteoblasts – these direct the formation and hardening (mineralisation) of the bone;
- Osteoclasts – have an opposite function to osteoblasts, they break down or reabsorb bone;
- Osteocytes appear to control the level of osteoblast and osteoclast activity – these cells can sense changes in bone loading and initiate an appropriate modeling or remodeling response.



From:
http://cellbio.utmb.edu/microanatomy/bone/cartilage_and_bone_cells.htm

Bone modeling is the term given to the growth (lengthwise) and shaping of bones. This process allows bone to maintain its shape and proportions as it grows. Modeling is important as the bone adapts to an increase in functional demands such as exercise.

Bone remodeling is a repair process that occurs on a continual basis. Remodeling first involves the removal of some bone over the bone surface, followed at the same site by the formation of new bone. This new bone is eventually mineralised, or strengthened by the addition of calcium and phosphorus. Remodeling also occurs during a fracture repair. More than 5% of total bone mass is "turned over" each year by the process of remodeling.

The relative balance of activity by osteoblasts and osteoclasts will govern whether there is a net gain or loss in bone mass – i.e. whether there is a balance in bone modeling/remodeling. Imbalances in bone modeling/remodeling may result in chip fractures, shin soreness and stress fractures.

Bone strength

Bone strength is the toughness or ability to endure stress; therefore is related to the ultimate load or stress at which bone will break. Because bone mineralisation provides compressional strength to bone, the bone mineral content (which is a measure of the amount of mineral in a bone) is an important determinant of bone strength during the development phase of an animals life [1, 2]. In humans, bone having the highest percentage mineral content with a large cortical area were shown to have the greatest strength [3].

In rapidly growing horses, bone development and maturity fail to keep pace with overall growth, thereby generating excess physical load and predisposing bone to deformity and fragility. Two of the most important factors thought to have an important bearing on the bone mineral content, and therefore bone strength are exercise and nutrition.

Effect of exercise on bone strength

Bone adapts to changes in physical loading and activities by modeling and remodeling. An increased load or strain is reported to increase the bone mass as modeling results in the addition of new bone. The reverse is also true; a decreased load will result in a reduction in bone mass.

Training

Appropriate exercise training should stimulate bone modeling, improve skeletal strength and in theory reduce the probability of exercise associated skeletal injuries. Currently, an incremental training program that gradually increases the length, speed and repetition of galloping is recommended for enhancement of bone strength.

Stabling

Confining horses to stables may also affect bone strength, with studies describing decreases in bone mineral content in horses kept stabled. Confining yearlings to stables with limited daily exercise results in a decrease in the mineral content of the cannon bone compared to yearlings kept at pasture. Interestingly, this difference in bone mineral content was maintained when both groups of horses were subsequently conditioned for eight weeks (trot and gallop exercise five days per week).

In one study, horses were subjected to intense conditioning (exercised on a high speed treadmill) for 12 weeks during which time bone mineral content was found to increase by 1.1% per week [4]. Horses were then reduced to minimal conditioning to maintain fitness for 28 weeks (exercising on the treadmill for 20 min 2d/wk, and walking at 1.1m/s for 30min/d for an additional 2d/wk) during which time the bone mineral content remained unchanged. Next they were subjected to stable rest deconditioning (horses were walked at 1.1m/s for 60min/d in two 30min sessions 7d/wk) for 12 weeks, during which the bone mineral content decreased linearly by 0.45% per week. In another study, immobilisation of the left forelimb of horses for 8 weeks resulted in a decreased bone mineral content in both front limbs [5]. These progressive decreases in bone mineral content are most likely associated with decreases in mechanical stimulation.

Spelling

Long breaks from training either voluntarily or forced by an injury will lead to a decrease in bone mass and strength. Long spells could result in a substantial decrease in bone mineral content (and strength) that must be gradually regained during subsequent conditioning. The longer the spell, the more gradual the increase in the volume and intensity needed to minimise the risk of excessive strain on bone. In thoroughbred racehorses, spells of greater than two months have been associated with an increased frequency of fractures of the humerus shortly after return to racing [6]. These studies further emphasise the need to caution and care during resumption of training following spells.

Exercise and growing foals

Studies indicate that confinement of foals up to five months of age may result in retardation of normal development. In one study, the cross sectional area of the third metacarpal bone of warmblood foals was significantly larger in foals reared on pasture compared to foals boxed-reared [7]. In another study, five-month-old weanlings confined in stalls and subjected to 82 m per day sprinting for five days per week for eight weeks appeared to have greater third metacarpal bone cortical size and mineral content than did foals confined in stalls or yarded [8]. However other studies have suggested that sprinting may lead to an overstimulation of bone, resulting in less active mineral deposition in the longer term [9].

Nutritional factors affecting bone health

Calcium and phosphorus

Calcium and phosphorus comprise 70% of the mineral content of bone and an adequate supply of these minerals is critical for maintenance of bone mineral content and strength.

Current National Research Council (NRC) recommendations for dietary calcium are 0.3% for maintenance and 0.32% for very heavy work (i.e. racing requirements) [10]. Supplementation of calcium has not been shown to be effective in preventing a decrease in bone mineral content during deconditioning or resting [11]. However, bone mineral content did increase in horses supplemented with additional calcium during conditioning, compared to horses fed a control diet (i.e. those levels recommended by the NRC). Thus, calcium supplementation above currently recommended levels increased bone mineral content in conjunction with conditioning but not in the absence of conditioning.

These studies indicate that younger horses in training undergoing more bone modeling than mature horses might be more sensitive to an inadequate supply of calcium or phosphorus, or a calcium:phosphorus (Ca:P) imbalance and that further supplementation of calcium may be a useful measure for improving bone mineral content during conditioning. This work has been supported by other studies in women, which describe the positive effect of a combination of exercise training and calcium supplementation on bone mineral content [12, 13].

Cereal grains are typically low in calcium and fairly high in phosphorus, brans are very high in phosphorus and lucerne hay is around 1.0 – 2.0% calcium while grass hays are 0.3 – 0.4% calcium. Commercially available feeds and supplements vary widely in their calcium and phosphorus levels.

At a time of increased bone modeling and remodeling, it is possible that added dietary calcium might allow for great bone mineralisation and strength. It is important to consider all the components of the ration to ensure the diet not only provides adequate calcium, but that it also provides an optimal ratio of calcium to phosphorus, particularly in young horses.

Other nutrients of importance

Vitamin D plays a vital role in the regulation of calcium and phosphorus metabolism and has a major regulatory role in bone metabolism and strength. Several studies in humans have shown vitamin D and calcium supplementation to significantly reduce fracture rates and bone loss [14, 15]. Aside from vitamin D, vitamins B6, C and K have been shown to be integral to bone health because of their involvement in the synthesis of matrix constituents such as collagen and osteocalcin and formation of collagen crosslinks [16]. Nutrient intakes of potassium, protein and lutein were also found to be significantly associated with bone mineral density [17] and a deficiency of copper has been shown to decrease collagen crosslink formation and to lower mineralisation [18].

Supplemental protein and carbohydrate as energy sources are also important for bone health. There are however some reports in humans that excess protein intake can produce a negative calcium balance and stunt bone growth [19]. This further supports the requirement for supplementation of calcium to maintain optimal calcium balance and bone health.

Other factors which may affect bone strength include:

Growth, Gender, Aging

- Bone mass increases with growth and bone strength is proportional to its mass [2, 20].
- Researchers found that by one year of age, on average horses achieve approximately 76% of the maximum bone mineral content and about 85% of maximum strength [2]. In this study, maximum bone mineral content and breaking strength was reached at six years of age, peaking after most race horses have completed their careers.
- Size differences, as well as hormonal differences may result in differences in growth and bone strength between sexes [21].

Genetics

- In a number of studies of humans and other mammalian species, bone density has been shown to be a heritable trait [22].

Infection and Immunity

- Infection and stress can be risk factors for bone integrity leading to bone weakness [21].

Hormones and cytokines

- Growth hormone facilitates cortical bone growth, whereas steroid hormones affect cancellous bone formation [23]. Other hormones and cytokines have a profound effect on bone metabolism, growth and remodeling and therefore are consequential to their strength [21].

Nutrition is central to the maintenance of skeletal health. Studies reported here indicate that through strategic nutritional manipulations and management practices, it may be possible to increase or preserve bone mass and to maintain bone strength.

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