J. Phys. Ther. Sci. 29: 763–766, 2017

The Journal of Physical Therapy Science

Case Study

Nonhealing, progressive stress fractures of the foot in a 13-year-old basketball player: is vitamin K deficiency a risk factor?

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Abstract. [Purpose] To report an adolescent male basketball player with nonhealing stress fractures of the foot and discuss the probable factors. [Subject and Methods] A 13-year-old basketball player presented with right foot pain. He had been playing basketball for three years and practicing 5 days/week. He denied any increase in daily training intensity. Magnetic resonance imaging confirmed stress fractures of the cuboid and cuneiform, with mild edema of the soft tissues between the tarsal bones and tenosynovitis of the flexor hallucis and flexor digitorum longi. The foot was immobilized for 4 weeks, with progressive weight bearing introduced at the fifth week. At the 6th week, while still restricted to partial weight bearing, he reported diffuse severe pain. The entire foot was painful with palpation, and new imaging showed stress fractures of the talus, cuboid, cuneiform, and proximal first metatarsal bones, and tenosynovitis of the flexor hallucis longus and flexor digitorum longus tendons with progression of the soft tissue edema around the tarsal bones. Acute phase reactants were elevated; vitamin K level was low. [Results] He started participating in games again at the 6th month post-injury. [Conclusion] Management of patients with stress fractures includes immobilization, physical therapy, and biomechanical arrangements. If the expected healing does not occur, a deficiency of vitamin K might be considered as a factor. Questioning on dietary habits of the patient and encouraging adequate intake of the deficient nutrient might assist in the healing process.

Key words: Stress fractures, Vitamin K

(This article was submitted Oct. 20, 2016, and was accepted Dec. 21, 2016)

INTRODUCTION

Stress fractures occur due to repetetive loading of the bones with submaximal stress rather than a single traumatic event. They can occur in all bones of the lower extremity, particularly in people predisposed to repetetive strain, such as athletes. Any sports involving repetitive jumping, cutting, landing, long distance running, tennis, basketball may predispose the athlete to stress fractures. The incidence increases with a sudden increase in intensity or duration of training, poor physical conditioning, or incorrect footwear. Excessive forefoot or ankle varus, leg length discrepancy, a high or low longitudinal arch, muscle imbalance and tightness are other risk factors. In women, repeated stress, low bone mineral density and dietary restraint have been reported as a specific risk triad[1)]. Stress fractures account for up to 7% of all sports injuries[2)].

Vitamin K promotes clotting and is involved in the activation of important proteins in blood coagulation, prothrombin (II), factor VII, factor IX, and factor X, as well as protein C and protein S. Deficiency of these factors can result in defective clotting and a bleeding disorder. When vitamin K was discovered, it was believed to have only the role of supporting coagulation, and it was given the name 'K' because of the German word *Koagulation*. Because of low plasma concentration, vitamin K has been assessed by functional methods, using prothrombin time to determine its effect on clotting time. Further research

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has shown that it also functions as a coenzyme that enhances calcium incorporation into bone. The currently known forms of vitamin K can be grouped into the following three categories: vitamin K1 (Phytomenadione or phytomenadione), vitamin K2 (menaoquinones), and vitamin K3 (menadione). Vitamins K1 and K3 are fat-soluble, whereas vitamin K2 is water-soluble. Technically, only vitamin K1 is recognized as a true vitamin, which is essential for human and animal well-being and present in fresh green vegetables such as broccoli, cabbage, lettuce, and spinach. Vitamins K2 and K3 can be derived as metabolites of vitamin K1 in various tissues or the gastrointestinal tract in animals or humans. It has been shown that vitamin K2 modulates the genetic expression of collagen type 1 and osteocalcin which leads to increased produciton of these proteins by osteoblasts[3]. Its reducing effect on osteoblasts' apoptosis[4] and stimulating effect on other bone blastic proteins, such as osteoprotegerin and osteopontin[5], have been reported. Regarding bone remodelling resorption, the reduction of osteoclast production from bone marrow cells[6] and induction of osteoclasts' apoptosis have been documented. These metabolic effects are achieved through vitamin K2's ability to downregulate inflammation (IL-6, PGE2) and cell proliferation while increasing apoptosis[7]. It should be emphasized that this would be effective only if osteoclastic activity is excessively high. Vitamin K2 may reduce the accelerated bone resorption induced by menopausal hormonal loss[8] or corticosteroid treatment[9, 10]. Vitamin K deficiency as a possible contributing factor for stress fractures has not been described before, although there are reports documenting its effect on osteoporotic femoral neck fractures.

SUBJECT AND METHODS

A 13-year-old basketball player was admitted complaining of right foot pain for the previous 5 days. A written informed consent was obtained from the patient's father. He had no remarkable medical history, except for a deficiency of vitamin K when he was 3 or 4 years old. He never had any bleeding disorder and the parents did not remember why vitamin K level was checked. He had been playing basketball since he was 10 years old. His practices were 1.5 to 2 hours/day, 5 days a week. He reported no recent increase in the intensity or duration of the training sessions. He did not have pain during normal activities of daily living, but he was unable to practice because of pain. He did not have any complaint on the left foot. Physical examination findings were tenderness of the plantar fascia and lateral side of the ankle with palpation, low medial longitudinal arches, and tight hamstrings and achilles tendons. Magnetic resonance imaging showed edema of the cuboid and third cuneiform bones, together with mild effusion of the surrounding soft tissues. Tendonitis of the flexor hallucis and digitorum longi were also present (Fig. 1). The foot was immobilized for 4 weeks and he received physiotherapy consisting of electrical stimulation (both TENS for pain relief and muscle stimulation for strengthening) and hydrotherapy during this time. His normal activities of daily living were allowed with the immobilized foot. Between the 4th and 6th weeks, he reported about 80% improvement of symptoms and partial weight bearing was allowed. He had only mild tenderness of the plantar fascia on palpation. At the end of the 6th week, he reported diffuse and more severe pain. He denied any weight-bearing more than was allowed. Diffuse tenderness on the dorsal and plantar surfaces of the foot was evident and ankle movements were painful and limited. Updated imaging was ordered and showed increased areas of edema of both the cuboid and the third cuneiform bones and surrounding soft tissues when compared with the first imaging. There was also edema of the talar bone on the navicular side and the proximal first metatarsal bone which had not been present prior. Tenosynovitis of the flexor hallucis and digitorum longi persisted (Fig. 2). Laboratory tests were ordered on account of these findings. The test results were as follows (NR, normal range):

Hb: 11.5 g/dl (NR: 11–16), erythrocyte sedimentation rate (ESR): 33 mm/h (NR: <15), C-reactive protein (CRP): 1.75 mg/dl (NR: <0.22), rheumatoid factor (RF): 8 IU/ ml (NR: <14), antinuclear antibody (ANA): negative, fasting blood sugar: 104 mg/dl (NR: 70–100), calcium: 10 mg/dl (NR: 9.2–10.7), phosphorus: 4.6 mg/dl (NR: 3.1–5.3), alkaline phosphatase (ALP): 263 U/L (NR: 169–618), parathormone (PTH): 38 pg/ml (NR: 14–72), vitamin D, 25 hydroxy: 28.2 ng/ml (NR: 25–80), vitamin B12: 592 pg/ml (NR: 200–835), blood urea nitrogen (BUN): 9 mg/dl (NR: 4.67–22.43), creatinine: 0.79 mg/dl (NR: 0.5–1.1), ALT: 22 U/L (NR: 16–59), AST: 18 U/L (NR: 10–36).

Although not routinely ordered in practice, as the parents reported a nonspecific history, and the other findings did not explain the clinical situation, serum vitamin K level was ordered, with the result <0.1 ng/ml (NR: 0.1–22). At the time of blood sampling for vitamin K testing, fasting blood sugar test was repeated because of the above-normal range during the first test; the result was 88 mg/dl. Dietary habits were also questioned; an exact food diary could not be obtained, but his parents stated that he had fresh green vegetables like broccoli and lettuce on an average of 3 to 4 times per week. Overall, his diet was quite balanced, with consumption of lean meat or fish, dairy products, citrus fruits on a daily basis. He had fast food for at least 3 meals per week. He did not take any supplementary vitamins or minerals.

RESULTS

His foot was immobilized for an additional 2 weeks, and partial weight bearing was then allowed. During the total and partial non-weight bearing periods, he performed isometric exercise and hamstring and achilles stretches. He was encouraged to consume more fresh green vegetables for at least one meal per day. Following 5 months from the beginning of the symptoms, he started practicing with longitudinal arch supports; he started participating in games at the 6th month.

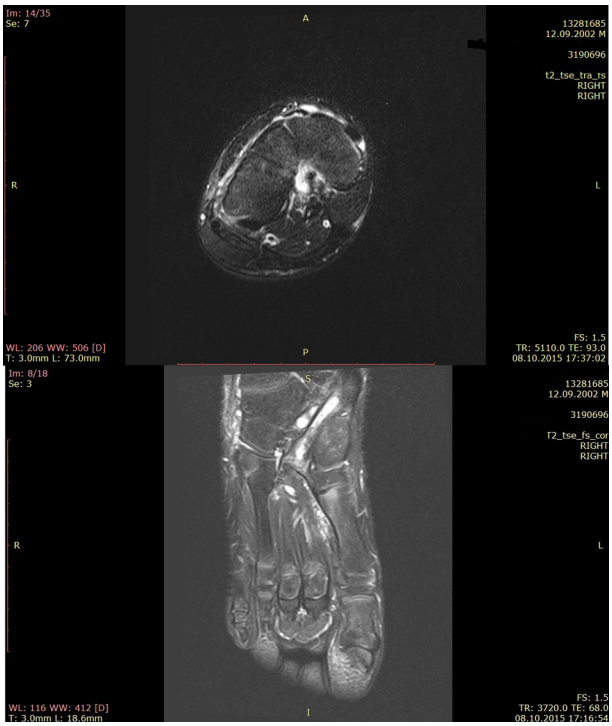

Fig. 1. Magnetic resonance imaging (MRI) findings of the patient on admission showing edema of the cuboid and third cuneiform bones, mild effusion of the surrounding soft tissues, tendonitis of the flexor hallucis and digitorum longi

Fig. 2. Magnetic resonance imaging (MRI) findings of the patient at 6th week showing increased areas of edema of both the cuboid and the third cuneiform bones and surrounding soft tissues, edema of the talar bone on the navicular side and the proximal first metatarsal bone, tenosynovitis of the flexor hallucis and digitorum longi

DISCUSSION

Stress fractures of the lower extremities are common in athletes and they are being more commonly diagnosed both by increased awareness of the physicians and by imaging techniques. Predisposing factors should be corrected for the purposes of treatment planning. Gait, limb length discrepancy, and tightness of the proximal muscles and tendons should be noted in the physical examination as well as the general appearance of the foot regarding shape, deformity, swelling, pain and tenderness, and range of motion. The present case exhibited low medial longitudinal arches and tight hamstrings as well as short achilles tendons; these were all predisposing factors for stress fractures. These factors were appropriately corrected during the treatment process and after the patient returned to sport. In general, the severity of the fracture and pain can dictate how soon an athlete can re initiate regular training. In this case, the initial expectation was to restart training with a gradual increase in intensity after 6 weeks however, this was no achieved in our case. A second magnetic resonance imaging was ordered as the patient's symptoms and physical examination findings progressed despite treatment. Metabolic and nutritional issues are recommended to be considered in bilateral stress fractures[11]. Although this case was not bilateral, as the condition progressed, these issues were considered. All predictors of calcium metabolism were within normal limits. ESR and CRP were elevated; this was not unexpected as there was an inflammatory reaction in the body. A very slight increase in fasting blood sugar was evident. It was rechecked in the same sample extracted to test vitamin K level, and shown to be within the normal range. Serum vitamin K level is not routinely checked as it is found in very low concentrations in the serum; instead, prothrombin time is used to determine its effect on clotting time. The patient had no history of any bleeding disorder, including no excessive bleeding after circumcision. The parents did not recall the patient's previous history of serum vitamin K level . Although the previous test results were unavailable, it was reported to be low. They had not been advised to take any action on the situation. After finding the level to be lower than normal limits, we investigated his dietary habits, as vitamin K is found in green leafy vegetables such as spinach, broccoli, lettuce, and others. Our patient had some of these vegetables as part of his diet, but like many of teenagers of his age, he was not motivated to consume them. Poor vitamin K staus is reported to be associated with low bone mass, osteoporosis, and fracture risk in adults[12–14], but its relationship with stress fractures has not been reported. Considering the effects of vitamin K on osteocalcin, it was concluded that the vitamin K requirement of children is much larger than that of adults because osteocalcin synthesis is at least 10-fold higher during growth than after

peak bone mass has been reached[15]. In an epidemiological study investigating the association of hip fracture incidence and intake of calcium, magnesium, vitamin D, and vitamin K in Japan, a striking pattern of high intake of vitamin K and low incidence of hip fractures in eastern areas of Japan was apparent, with the opposite pattern—a low intake of vegetables rich in vitamin K and a high incidence of hip fracture—in western areas[16]. The observers found significant inverse associations between hip fracture incidence and each nutrient, but after adjusting for covariates, the strongest correlation was seen with vitamin K.

The effects of calcium and vitamin D on bone metabolism are very well known with no doubt that individuals should have adequate intake through diet and/or supplements. The need is increased in certain conditions like adolescence, pregnancy, and post-menapausal states. Calcium and vitamin D deficiency may lead to both osteoporotic fractures and stress fractures. The deficiency of vitamin K, apart from its effects on bleeding, has been linked with osteoporotic fractures; however, it has not currently been related to the poor healing of stress fractures. In the present case, there were clear risk factors such as repetitive loading with poor mechanics resulting from low medial longitudinal arches, tight hamstrings, and achilles tendons. However, although measures to treat the condition were taken, the progress was not as expected, and progressively worsened. Assessing serum vitamin K level was not initially planned until the parents reported that a previous history was present. The patient's eating habits were like most of the adolescents of his age, but he was not very strict on eating no vegetables. He cooperated when he was encouraged to increase the amount of green vegetables in his diet.

The present case cannot be directly related to vitamin K deficiency alone, and, as mentioned above, an unhealing stress fracture due to vitamin K deficiency has not been reported previously. The patient returned to full sport activities at the 6th month, which is the approximate time period to be expected with many types of stress fracures. Thus, a claim that increasing the amount of green vegetables in his diet necessarily improved the situation is unfounded. Additionally, a follow-up vitamin K level assessment was not performed and it is not known whether the level reached normal limits after the dietary changes. In conclusion, along with assessing calcium and vitamin D status, which has a very well-documented effect on bone metabolism, we advise questioning on consumption of green vegetables to gain a full picture on the potential vitamin K level in patients with stress fractures, especially if healing does not occur as expected. If a poor status is confirmed, encouraging the patient to consume green vegetables in at least one meal a day might assist in the healing process. It is not recommended to examine serum vitamin K levels in patients with stress fractures on a routine basis.

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