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Stress Fractures in Athletes

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Abstract

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During the 14-year period of 1971–1985, 368 stress fractures in 324 athletes were treated. The series contained 268 fractures in males and 100 fractures in females; 32 fractures occurred in children (< 16 years), 117 in adolescents (16–19 years), and 219 in adults. Forty-six fractures were incurred by athletes at an international level, 274 by athletes at a national or district level and 48 by recreational athletes. Of the total cases, 72% occurred to runners and a further 12% to athletes in other sports after running exercises.

The distribution of the stress fractures by site was: tibia 182, metatarsal bones 73, fibula 44, big toe sesamoid bones 15, femoral shaft 14, femoral neck 9, tarsal navicular 9, pelvis 7 olecranon 5 and other bones 10.

Of the total fractures, 342 were treated conservatively and 26 fractures required surgical treatment. The operative indication was dislocation in 5 cases and delayed union/nonunion in 21 cases. The sites most often affected by delayed union were: anterior midtibia, sesamoid bones of the big toe, base of the fifth metatarsal, olecranon, and tarsal navicular.

The athletes at an international level experienced the greatest risk of multiple separate fractures, protracted healing, or fractures requiring surgery.

Key words: athletic injuries, fractures, running, mechanical stress

Introduction

The annual incidence of stress fractures in Finnish conscripts is 0.73% (51), while Orava (44) has estimated that about 3% of athletes in a Finnish town population suffer an exertion injury annually and 0.12% a stress fracture. Stress fractures comprise 4%–14% of runners' overuse injuries, depending on the nature of the clinic at which they are treated (8, 24, 34).

The bone scan has made the diagnosis of a stress fracture possible at an earlier date than with clinical or radiological methods. It becomes positive 2–3 weeks before the radiographs and is thus valuable when the clinical diagnosis is in doubt or when evidence is needed to convince the patient to cease training (15 26, 28, 34, 49, 54).

The intrinsic and extrinsic etiological factors of stress fractures have been described in depth (8, 15, 24, 33, 34, 40, 57, 60).

With the exception of stress fractures of the femoral neck, the middle third of the tibial shaft, and the patella, these lesions have been considered innocent and were treated by interruption of training in almost all cases (2, 3, 11, 12, 15, 24, 41, 42, 50).

The basic pathophysiology of stress fractures has nevertheless remained somewhat vague despite the accumulation of new information on forces acting upon bones (1, 4, 5, 7, 14, 18, 48, 56, 63). Prevention of stress fractures has proved to be problematic even under the well-controlled army conditions (51), although some progress has been made (55). Also, it has been shown in several recent reports that many stress fractures tend to exhibit delayed union or nonunion, requiring either a very long period of rest or surgical therapy before healing takes place (10, 19, 20, 21, 22, 46, 61, 62).

We have analyzed a series of 368 cases of stress fractures in Finnish athletes to obtain some basic data and identify factors leading to multiple fractures, slow healing, and a need for surgical therapy.

Material and Methods

During the 14-year period of 1971–1985, 368 stress fractures in 324 athletes were seen and treated at the Clinic of Sports Medicine of the Deaconess Institute in Oulu, the University Hospital of Oulu, the Keski-Pohjanmaa Central Hospital, and the Medirex Clinic of Sports Medicine at Kokkola, Finland.

All fractures were examined clinically and radiologically. A bone scan was performed in 70 cases (19.0%) with typical history and clinical findings and negative initial radiographs. The diagnosis was confirmed in these cases with new X-rays after 4 weeks. A special form was used to record the history, clinical, radiological, and bone scan findings, the therapy, and the eventual outcome. The material was analyzed on the basis of fracture cases as the same patient could have separate fractures at different ages and after different training regimes.

Statistical analysis was performed using the two-sample t test and the chi-square test.

Age and Sex

The series contained 268 fractures in males (72.8%), with a mean age of 23.3+7.1 years, and 100 fractures in females

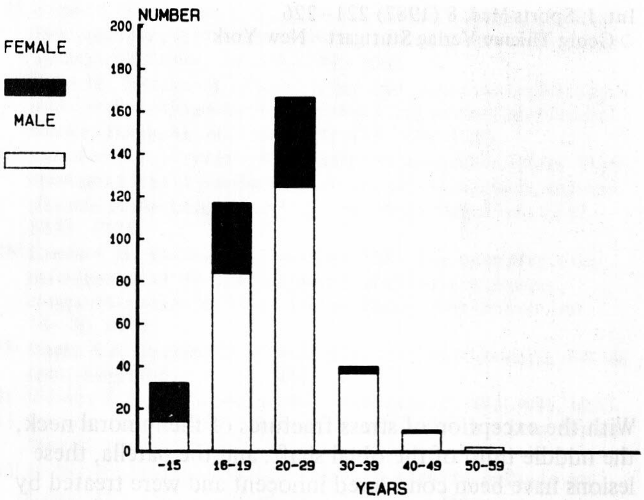

Fig. 1 Stress fractures in athletes. Age and sex.

(27.2%), with a mean age of 20.0+5.4 years (Fig. 1). The mean age of the whole population was 22.4+6.9 years. Thirty-two fractures (8.7%) occurred in children (< 16 years), 117 (31.8%) in adolescents (16–19 years), and 219 (59.5%) in adults (20 years).

Achievement Level and Intensity of Training

Forty-six fractures (12.5%) were incurred by athletes at an international level, 274 (74.5%) by athletes at a national or district level and 48 (13.0%) by recreational athletes. Training had been regular for more than 2 years in 305 cases (83%), for 1–2 years in 33 cases (9%), and for less than 1 year in 22 cases (6%). Training had taken place 6 or more times a week in 264 cases (72%), 3–5 times a week in 95 cases (26%), and 1–2 times a week in 9 cases (2%).

Sports Events

The distribution of the fractures among the various sports is given in Table 1.

Results

Stress Fracture Sites

The distribution of the 368 stress fractures by site is given in Table 2. There were significantly more metatarsal ($P <$ .05) and pelvic stress fractures ($P <$ .01) in females and significantly more fibular stress fractures ($P <$ .005) in males (Fig. 2). There were no significant differences between the children, adolescents, and adults in this respect.

Competitive athletes had stress fractures in the tibia significantly more often ($P <$ .01) (Fig. 3), while the recreational athletes significantly more often had the metatarsal bones and the pelvis affected ($P <$ .05).

The distribution of stress fractures among the anatomical parts of the lower extremities in the various sports is shown in Table 3. There were no significant differences between the various running events or between these and the ball games. There were significantly more stress fractures in the tarsal bones of jumpers than of sprinters ($P <$ .01).

Table 1 Sports represented in the stress fracture series.

Sports and events	*N*	%	M/F
Running	265	72.0	203/62
Long-/middle-distance	158	42.9	132/26
Sprinting/hurdling	39	10.6	22/17
Jogging	46	12.5	31/15
Orienteering	22	6.0	18/4
Jumping	18	4.9	13/5
Throwing	9	2.5	6/3
Other track and field events	10	2.7	3/7
Skiing	32	8.7	26/6
Ball games	24	6.5	20/4
Miscellaneous	10	2.7	5/5
Total	368	100.0	271/97

Table 2 Stress fracture sites.

Bone	*N*	%	M/F
Tibia	182	49.5	139/43
Proximal third	89		66/23
Middle third	27		20/7
Distal third	66		53/13
Metatarsal bones	73	19.8	45/28
II metatarsal	23		16/7
III metatarsal	29		16/13
IV metatarsal	10		5/5
V metatarsal	11		8/3
Fibula	44	12.0	40/4
Sesamoid bones (MTP I)	15	4.1	8/7
Femoral shaft	14	3.8	13/1
Femoral neck	9	2.4	5/4
Tarsal navicular	9	2.4	6/3
Pelvis	7	1.9	2/5
Olecranon	5	1.4	4/1
Talus	2	0.5	2/0
Proximal phalanx of I toe	2	0.5	0/2
Metacarpal bones	2	0.5	2/0
Miscellaneous	4	1.2	3/1
Total	368	100.0	271/97

Multiple Fractures

In total, 290 athletes had 1 single fracture, 4 had 2 simultaneous fractures, 25 had 2 separate fractures, 1 had 3 separate fractures, 3 had 4 separate fractures, and 1 had 5.

Athletes at an international level had multiple fractures significantly more often than those at lower levels ($P <$ .005). All the multiple and simultaneous fractures occurred in the lower extremities.

None of the 30 athletes with multiple separate fractures had a second fracture at the same site. The new fracture occurred on the contralateral side on 24 occasions and on the same side as previously in 15 instances.

Fig. 2 Typical supramalleolar stress fracture of the fibula.

Fig. 3 Typical oblique posteromedial stress fracture of the tibial diaphysis.

Fig. 4 Delayed union of a stress fracture in the proximal part of the fifth metatarsal.

Table 3 Sports and stress fracture sites in the lower extremities.

Event	Pelvis	Femur	Lower leg	Tarsal bones	Fore-foot
Long- and middle-distance	2	11	103	2	39
Sprinting and hurdling	–	–	28	1	10
Jogging	3	3	23	–	16
Orienteering	–	2	18	–	1
Jumping	1	–	12	5	1
Skiing	–	5	20	1	6
Ball games	1	–	13	2	7

Table 4 Healing of stress fractures.

Bone	Healing period		
	2–4 weeks	1–2 months	> 2 months
Tibia			
Proximal third	–	38	51
Middle third	–	13	14
Distal third	–	35	31
Fibula	3	33	8
Metatarsals	15	42	17
Sesamoid bones	–	–	15
Femoral shaft	1	1	12
Femoral neck	–	–	9
Pelvis	–	2	5
Olecranon	–	–	5

Delayed Healing

There were 36 stress fractures (9.8%) with delayed healing or nonunion. Athletes at an international level had delayed union or nonunion significantly more often than athletes at lower levels ($P < .01$). The bones affected were: sesamoid bones of the big toe 15, midtibial shaft 6, base of the fifth metatarsal 4, tarsal navicular 4, olecranon 4, and proximal tibial shaft 2 (Fig. 4).

Degree of Disability

In 283 cases (77%) there were symptoms only during training, in 48 cases (13%) there were symptoms in everyday life, and in 37 cases (10%) sick leave was needed.

Treatment

1. Conservative treatment: 342 fractures (92.9%) were treated conservatively including 322 cases in which rest from training was the only treatment modality. Plaster of Paris was used in 10 cases, non-weight-bearing with crutches in 2 cases, non-weight-bearing and an elastic bandage in 3 cases, an elastic bandage alone in 2 cases, and a special functional orthosis in 2 cases.

2. Surgical treatment: 26 fractures (7.1%) required surgical treatment. These affected athletes at an international level significantly more than athletes at lower levels ($P < .001$).

The indications for operative treatment were:

1. Dislocation, 5 cases (femoral shaft 3, proximal tibial shaft 1, talus 1).

2. Delayed union/nonunion, 21 cases (midtibia 5, sesamoid bones of big toe 5, base of the fifth metatarsal 4, olecranon 3, tarsal navicular 3, proximal tibial shaft 1).

Fifteen delayed and nonunions were treated conservatively. The surgically treated patients were in most cases top athletes not prepared for long training pauses.

Outcome of Treatment

The healing periods for stress fractures at various sites are shown in Table 4. Two surgically treated patients had refractures which required another operation (femoral shaft and olecranon).

In 367 cases the athletes could resume training, but one very promising middle-distance runner had to terminate his career because of a nonunion of the tarsal navicular with osteoarthrosis.

Discussion

Prozman and Griffis have shown a 12 times higher incidence of stress fractures in women than in men under similar military training conditions (50). Orava notes that 14.4% of athletes' overuse injuries occurred in women (44). In this series 26.4% of stress fractures occurred in women, which seems to indicate that female athletes also suffer more from stress fractures than males. The more slender bones, the gait differences, and the unfavorable biomechanical conditions during running caused by a wide pelvis, coxa vara, and genu valgum have been offered as possible explanations (47, 60). The significantly lower mean age of the female athletes may also indicate that the girls were not as accustomed to hard training as the boys (37).

Stress fractures in children are rare, but their incidence is increasing (38, 45), and they are as common in adolescents as in adult athletes, even though the adolescents suffer less from overuse injuries in general (44). The lamellar bones of children and adolescents do not have as long a fatigue life as the osteonal bones of adults (13, 25).

Running causes the great majority of stress fractures (33, 34, 43, 60), and 72% of the cases in our series occurred to runners, with a further 12% occurring to athletes in other sports after running exercises. The distribution of cases between the sports was most even among athletes at the international level. Almost any sports event can cause stress fractures (2, 23, 31, 39, 43, 52, 62), although among the mass sports, swimming seems to be very safe in this respect.

As expected, the most common stress fracture location in the runners and in all subjects of this series was the tibia (2, 8, 58, 59, 60), but in contrast to some earlier reports we found that compression stress fractures were as common in the proximal end of the bone as in the distal end (2, 60).

Jumpers have a predisposition to stress fractures in the tarsal bones (17, 61), and it has also been reported recently that recreational runners relatively easily suffer from tarsal fractures (32). The most typical stress fracture connected with throwing was the stress fracture of the olecranon in javelin throwers (20). A new finding was the high incidence of stress fractures of the sesamoid bones of the big toe (19). One of the most common stress fractures in soldiers, the calcaneal stress fracture, is very seldom seen in athletes (17, 26, 32, 36, 60, 65).

In principle, the treatment of stress fractures in athletes is conservative, involving rest from the activity causing the symptoms (24, 41, 43, 15). Radiologically "acute" stress fractures of the fifth metatarsal base, the talar neck, and the tarsal navicular nevertheless require immobilization with non-weight-bearing to guarantee normal healing (6, 61, 62). Other stress fractures with an inherent tendency for delayed healing are those of the olecranon, the sesamoid bones, and the anterior midtibia (19, 20, 46). Clear indications for surgical therapy are dislocations and nonunions, and surgery is also indicated in some cases of delayed union when the interruption in training threatens to become disproportionately long (10, 19, 20, 21, 22, 61, 62). The highly motivated athletes engaged at the international level seem to experience the greatest risk of multiple separate fractures, protracted healing, or fractures requiring surgery.

The most important external etiological factors involved in stress fractures are training errors ("too much too soon"), excessively hard training surfaces, and inadequate shoes (17, 24, 27, 38, 57). Of the intrinsic factors, the most important seem to be excessive pronation of the foot (forefoot varus, subtalar varus, tibial varum), unequal length of the lower extremities, pes cavus, and muscular insufficiency (8, 16, 30, 57, 60).

Christopher Vaughan writes in a review on the biomechanics of running: " . . . it is disappointing that few workers appear to have addressed the more fundamental issue: what conditions predispose a particular runner to stress fractures and how can these conditions be avoided?" (63). These are crucial questions because stress fractures seem to be increasing both in athletes and soldiers at least in Finland (Orava, personal communication, 51). From the prophylactic point of view, it would be very important that those athletes with increased risk, i.e., women, children, adolescents, and runners with malalignments and excessive pronation, be kept under close surveillance. This would require close cooperation between the athlete, the coach, and the physician. The routine training programs ought to be adapted to the special qualifications of the athlete in question. The problem of prevention seems very difficult to solve in this way, however, because many young athletes in particular train without a coach, many coaches do not know enough about the prevention and early diagnosis of overuse injuries, and the cooperation mentioned above is lacking (17, 24, 38, 53). Scully and Besterman applied the cyclical principle to skeletal conditioning in military training by letting the trainees have a modified rest period during the 3rd week of training, whereupon the incidence dropped by 4.3%–1.6% (55). The idea was to let the damaged bone repair by osteonization and periosteal new bone formation. The principle of skeletal conditioning ought to be applied always when the intensity or the quantity of training is increased. The number of competitions during the high season must also be kept within reasonable limits. Skeletal conditioning has not yet attracted much interest in connection with sports medicine or coaching (29). The high ground reaction forces during running and jumping should be reduced with good quality sport shoes and the judicious selection of training surfaces (1, 4, 24, 40).

The gradual intensification of training programs in all age groups will make the disappearance of stress fractures unlikely. A lot of emphasis should therefore be placed on the earliest possible diagnosis of stress-induced bone lesions and the provision of effective primary treatment for them.

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