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RISK FACTORS FOR THE DEVELOPMENT OF STRESS FRACTURES: A CASE CONTROL STUDY

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ABSTRACT

Objective: To identify the risk factors for the development of stress fractures in this sub population in our country.

Study Design: Comparative cross sectional study.

Place and Duration of Study: Combined Military Hospital Abbottabad Pakistan, from Jan 2015 to Aug 2017.

Methodology: This study was conducted to identify different variables as risk factors for stress fractures in training cadets. We analyzed age, gender, running and sports prior to joining training, duration of marching, daily milk and carbonated drinks consumption, cigarette smoking, serum albumin, calcium and vitamin D levels, calf muscle diameter, leg length discrepancy and tibiofemoral angles.

Results: A total of 275 participant included in this study, 140 cases, 51% and 135 controls, 49%. Mean age was 20 years. Two hundred and sixty eight (97%) were males and 7 (3%) were females. Grade-2 stress fracture was the commonest with 63 (45%) cases. Regular daily running prior to joining training $p<0.006$, regular milk intake $p<0.005$ were found to have a protective effect while subnormal serum calcium level $p<0.001$, serum vitamin D insufficiency $p<0.009$, thinner calf diameter $p<0.001$, heavy daily march $p<0.039$, leg length discrepancy $p<0.025$ were significant risk factors. Fourteen percent needed operative treatment.

Conclusion: Regular daily running prior to joining training, regular milk intake, thicker calf diameter has a protective effect, while subnormal serum calcium and serum vitamin D levels, daily heavy march, leg length discrepancy are significant risk factors.

Keywords: Risk factors, Stress fracture.

INTRODUCTION

A stress fracture represents the inability of a bone to withstand repetitive bouts of mechanical loading which results in structural fatigue[1]. Hence these usually happen in athletes. Across tri-service, an average of six individuals will sustain a lower extremity stress fracture for every 1,000-service members each year[2]. We don't have reliable statistics regarding its incidence.

Training activities, environment, skeletal and muscles mass, biomechanical, biological factors and gender are supposed to play a role. Femoral neck, patella, anterior tibia, medial malleolus, talus, navicular and fifth metatarsal are considered to be at high risk because of high tensile load and low blood flow[3]. Few biomechanical risk factors include a high degree of external rotation of the hip, pesplanus, pescavus and leg length discrepancy. Females are also considered at a greater risk especially those who restrict caloric intake, avoid high fat dairy foods[4]. Milk is the first-choice diet for persons belonging to all age groups[5], containing adequate amount of calcium. We presume that adequate serum calcium and vitamin D levels have a protective effect on bones.

After sustaining this, injury cadets and athletes undergo rest, treatment and rehabilitation, varying from weeks to months. Uncertainty prevails about their return to normal activities and resumption of training. A knowledge about the causative risk factors for the development of stress fracture may help in preventing or decreasing their incidence.

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We conducted thisstudy toidentify different variables likeage, gender, running and sports prior to joining training, duration of marching, daily milk and carbonated drinks consumption, cigarette smoking, serum albumin, calcium and vitamin D levels, calf muscle diameter, leg length discrepancy and tibiofemoral angles.

METHODOLOGY

This study was conducted to determine risk factors for stress fractures in training cadets, from January 2015 to August 2017 in Combined Military Hospital Abbottabad, Pakistan. All new cases of Kaeding grades 2, 3, 4, of any bone were included. All cases of recurrent stress fractures and grade 5 were excluded. A detailed tool pro-forma was used for variable assessment. The cases and controls all belonged to one of the following institutions like traning institutes. X ray was used in majority of cases for diagnosis although few required bone scan and MRI. Leg length discrepancy and tibiofemoral angles were measured by digital radiography. Calf diameter was measured by a measuring tape 15cm from tibial tuberosity. Heavy march was defined as more than 1-hourduration. Regular running and sports before joining training, milk and carbonated drinks consumption, cigarette smoking, serum calcium, albuminand vitamin D analysis were done. Consent was obtained from cases and controls and study was approved from hospital ethics committee. Statistical analysis was done using SPSS-20 and p-value ≥0.05 was considered statistically significant.

RESULTS

A total of 275 participant included in this study, of which 140 were cases (51%) and 135 were controls 49%. Mean age was 20.5 years. Two hundred and sixty eight (97%) were males and 7 (3%) were females. Table showing the distribution.

Table: Distribution of cases and controls according to category and gender.

	Male Cadets	Recruits	Medical Cadets	Female Cadets
Cases	109	21	6	4
Controls	94	35	5	3

Out of 140 cases, 78 (56%) were from 1st term, 46 (33%) were from 2nd term, 11 (7%) were from 3rd term, and 5 (4%) were from 4th last term. Grade-2 stress fracture was the commonest 45%, followed by grade 3 (40%) and grade 4 (15%). Twenty seven cases and 45 controls were regularly running daily and 112 cases and 89 controls were not running regularly prior to joining training, p<0.006. Fifty three cases and 76 controls were taking milk regularly while 85 cases and 59 controls were not[11]. Cases and 17 controls were smokers while 129 cases and 118 controls were non-smokers. Regular intake of carbonated drinks and serum albumin level was found insignificant risk factor. Sixty seven cases and 40 controls revealed subnormal serum calcium levels while 49 cases and 78 controls had normal levels, p<0.000. Similarly, vitamin D deficiency also corelated well with the risk of stress fractures, p<0.009.

Eighty nine (62%) cases were treated by prolonged rest, analgesics and supplementary calcium and vit D. Thiry three cases 24% were treated by plaster and non-weight bearing mobilization. Ten cases 8% were operated with closed reduction and internal fixation with interlocking intramedullary nailing, 4 cases 3% were operated by closed reduction internal fixation by cannulated screws, 2 cases (1.8%) were operated with open reduction internal fixation by locking compression plating, 1 case (0.6%) was operated with closed reduction internal fixation with interlocking intramedullary nailing, followed by open reduction and internal fixation with locking compression plating. One case (0.6%) was operated with dynamic hip screw and derotation screw.

DISCUSSION

Stress fractures were first described in 1855 by Breithaupt, who observed these injuries "march foot" in training recruits following long marches[6]. The skeleton is exposed to repetitive bone strain. Strain refers to the change in length per unit length of bone expressed as microstrain (μ€). Safety factor between usual strains (400-1500 μ€) and strains causing failure damage when introduced repetitively[1]. Thus, we usually see these injuriesin athletes and training recruits. In our part of the worldwe don't have reliable statistics for its incidence. This case control study is one such attempt to identify the possible risk factors.

These risk factors can be extrinsic and intrinsic. Extrinsic risk factors include type of activity or sports, training programme andequipment. Intrinsic risk factors are quality of bones, muscles, joints, biomechanical, biochemical factors and gender. Our study included variables like age, gender, running and sports prior to joining training, duration of marching, milk intake, carbonated drinks consumption, cigarette smoking, serum albumin, calcium and vitamin D levels, calf muscle diameter, leg length discrepancy and tibiofemoral angles.

Stress fractures can beof highor low-risk categories, depending on location and biomechanical stresses involved. High-risk stress fracture includes the femoral neck (tension side), patella, anterior tibia, medial malleolus, talus, navicular and fifth metatarsal. These sites share a characteristic region of high tensile load and low blood flow[3]. Anatomical regions such as the pelvis, sacrum, and metatarsals offer challenges due to difficulty in differentiating pathologies with common symptoms[7]. In our series, tibia middle one third was the most commonly involved site with 91 cases 66%, followed by tibia proximal third with 13 cases 9.5%, neck of femur 9 cases 7%, shaft of femur 8 cases 6%, shaft of fibula 4 cases 3%, metatarsals 6 (4.5%), tibia mid third bilateral 8 (6%), and medial malleolus 1 case (0.8%).

Speed runners load their feet relatively more than distance runners. In our study those cadets whowere doing heavy march daily more than one hour daily were at more risk of developing stress fractures than those undergoing light march less than one hour per day.

The shoes and inserts (insoles and orthotics), act as filters that alternate ground impact forces. Among trainees at high risk for stress fractures, prophylactic use of custom-made biomechanical orthoses may be warranted[8]. In our training academies the cadets march and drill wearing FT field training shoes whose soles are lined by metal encircling's and do sports and running in joggers while recruits march in DMS shoes (directly molded shoes, drill master shoes) and sports in joggers. These foot gear variables were not studied individually in our study. Milgrom[9] demonstrated that who are trained in a modified basketball shoes had a lower incidence of metatarsal stress fractures than those who trained in a standard infantry boot, there was no difference in the incidence of tibial or femoral stress fractures.

Figure-1: Displaced stress fracture of neck of femur.

Figure-2: Post-operative x-ray of figure-1, operated with closed reduction, internal fixation with dynamic hip screw and derotation screw fixation.

Stress fracture susceptibility is directly related to skeletal properties like bone mass, size and muscle factors[10]. We hypothesized that muscle mass has protective rather than causative effect acting as a shock absorber. During impact loading muscle is believed to act as an active shock absorber. In our study, 41 cases and 17 controls were having calf muscle diameter of 32cm or less, while 98 cases 117 controls had more than 32 cm of calf muscle diameter, thus confirming the protective role.

Figure-3: Complicated comminuted fracture shaft of tibia operated with closed reduction internal fixation with interlocking nail followed by minimally invasive plate osteosynthesis by locking compression plating and bone grafting.

Figure-4: Stress fracture shaft of femur was treated by closed reduction internal fixation by interlocking intramedullary nail. Radiograph shows consolidated fracture after 1 year.

Some biomechanical factors that may predispose athletes to stress fractures include a high degree of external rotation of the hip, pesplanus, pescavus and leg length discrepancy. Simkin[11] found that femoral and tibial stress fractures were more frequent in subjects with high arched feet whereas metatarsals were more frequent in low arched feet. We did not study the effects of abnormal arches in our study as all of them had been screened for these deformities earlier at the time of selection for training.

Physical fitness is a predictor of stress fracture risk. We agree with Milgrom[12] that personnel who played ball sports regularly for at least 2 years prior to basic training had less than half the risk of developing a stress fracture than the recruits who did not play ball sports. Our study shows that those cadets and recruits who were running regularly and playing sports regularly prior to joining training had a protective effect against development of stress fracture.

Gender factor contribute to stress fracture susceptibility with females being at a greater risk. Stress fractures have been found to be more likely to occur in females who restrict caloric intake, avoid high fat dairy foods, have eating disorder, and low percentages of ideal body weight[4]. Our female sample size of 7 (3%) is too less to assess the gender as a risk factor.

When stress fracture is suspected, plain radiography should be obtained initially and, if negative, may be repeated after two to three weeks for greater accuracy. An urgent diagnosis needs bones Cintigraphy or MRI. Both modalities have a similar sensitivity, but MRI has greater specificity[13]. Kaeding[14], classification includes Grade I asymptomatic stress reaction, Grade II pain with no fracture line, Grade III non-displaced fracture, Grade IV displaced fracture, and Grade V nonunion. This study used this system of classification. Grade 2 was the commonest with 63 (45%) cases, followed by grade 3, 55 cases (40%) and grade 4, 22 cases 15%. MRI and bone scan were used in some difficult diagnostic cases. A diagnostic ultrasound enjoys a higher sensitivity and specificity when compared to plain radiographs for early detection of stress fractures[15]. We did not use this diagnostic modality.

Milk is the first-choice diet for persons belonging to all age groups[5], containing adequate amount of calcium. Our 53 cases and 76 controls were taking milk regularly while 85 cases and 59 controls were not demonstrating its importance. Calcium, which is needed for bone mineralization, and vitamin D, which is needed for maintaining calcium homeostasis have been suggested as protective against stress fractures[16]. We found that 67 cases and 40 controls revealed subnormal serum calcium levels while 49 cases and 78 controls had normal levels. Similarly, vit D deficiency also corelated well with the risk of stress fractures, $p<0.009$. A negative correlation has been reported in the literature between bone mineral density and risk for stress fracture[17]. We have not analyzed this variable in our study. Smoking, intake of carbonated drinks, and serum albumin levels were found not to influence stress fracture.

Goldberg[18] found an annual incidence of 1.9% stress fractures inuniversity athletes, 67% were in freshmen. He emphasized the need to carefully monitor freshman training regimens. Our study supports his finding as 56% of cases were from 1st term, 33% were from 2nd term, 7% were from 3rd term, and 4% were from 4th last term. These finding suggest that as the physical training proceeds the bony wear and tear reaches an equilibrium thus making bones less susceptible to stress fractures. In the population, the incidence of stress fractures among females is greater than among men[19]. Our sample size of female gender is too less to assess the difference.

Markos[20] studied 88 athletes with lower limb stress fractures and anisomelia. Heopines that anisomelia seems to increase the possibility of stress fractures. We agree with him as in our study 47 cases and 30 controls were found to have leg length discrepancy while 93 cases and 105 controls were isomelic.

The management of stress fractures can be prolonged and difficult. The recruits and athletes can be out of training for weeks and months. Fredericson's[21] Grade 1 to 3 injuries are managed with crutch-assisted weight bearing until resolution of pain; bracing serves as a potential adjunct to reduce symptoms. For Grade 4 injuries, initially casting is recommended for a period of 6 weeks. Robertson[22] notes an increased role for surgical management of certain high-risk stress fractures to improve return times and rates to sport. Carlos[23] used focused shock wave treatments in professional athletes and personnel with a high rate of recovery, return to competition and pain control. We treated 89 cases 62% by prolonged rest, analgesics and supplementary calcium and vit D, all being grade 2. Thirty three cases 24% were treated by POP splintage and non-weight bearing mobilization for 4 to 8 weeks. These were mostly grade 3 cases. Ten cases 8% were operated with intramedullary nailing for fractures shaft of femur and tibia (fig-4). Four cases 3% were internally fixed by cannulated screws for fracture neck of femur. Two cases 1.8% were fixed by locking compression plating for fracture proximal tibia. One case 0.6% was operated with intramedullary nailing, later followed by minimally invasive plate osteosynthesis and internal fixation with locking compression plating and bone grafting for a very complicated highly communited fracture tibia fig-3. Another case 0.6% was operated with dynamic hip screw and derotation screw for fracture neck of femur fig-1 & 2. All the fractures ultimately united whether treated by non-operative or operative methods. All patients returned to their pre-injury training schedule gradually, except 2 cases, who in spite of surgery, rest, medication and physiotherapy could not further continue their training.

CONCLUSION

Training cadets and recruits like athletes are those set of subpopulations who are more susceptible to stress fractures due to their peculiar training activities. Diagnosis is easy in most of the cases by simple radiology. Daily regular running prior to joining training, regular milk intake, thicker calf muscle diameter has a protective effect, while subnormal serum calcium and serum Vit D levels, daily heavy march, leg length discrepancy are significant risk factors. A significant percentage needs operative treatment. Regular running on softer ground, milk intake and supplemental calcium are recommended for cadets intending to join training academy, while leg length discrepancy and vitamin D levels should be checked at the time of induction for screening of high-risk cadets.

CONFLICT OF INTEREST

This study has no conflict of interest to be declared by any author.

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