External Rotation of the Hip

A Predictor of Risk for Stress Fractures

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External rotation of the hip was found to have a statistically significant correlation with the incidence of stress fractures, in a prospective study among Israeli infantry recruits of possible anthropomorphic predictors of risk for stress fractures. Soldiers in whom hip external rotation was greater than 65° were at a higher risk for tibial and total stress fractures than those with external rotations of less than 65°. The mean hip external rotation in this study of 57° ± 9.3° was higher than in statistics reported in the American literature. The existence of a larger subpopulation with hip external rotation greater than 65° may partially explain why the reported incidence of stress fractures in the Israeli army is higher than that of the American army.

Stress fractures are a recognized hazard among military and athletic trainees. Their incidence has previously been found to vary significantly among different subpopulations participating in the same training. American army studies on recruits have shown that Caucasian men have a higher incidence of stress fractures than non-Caucasian recruits.[2] Likewise women had an increased incidence of stress fractures from less than 2 to 10%.[14]

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Supported partially by Grant #S 2-941, Langer Biomechanics Group, Inc.

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Received: June 27, 1985.

The incidence of stress fractures also differs greatly between armies. The less than 2% incidence reported for male American army recruits[2] contrasts with the 31% incidence reported among Israeli infantry recruits.[11] Giladi *et al.*[6] previously hypothesized that this difference between the American and Israeli armies could be explained by the existence of a population at increased risk to stress fractures in the Israeli army.

As part of a prospective study of stress fractures among infantry recruits, a detailed orthopedic physical examination was performed to see if anthropomorphic measurements could identify recruits at high risk to stress fractures. The correlation between one of the parameters studied, external rotation of the hip, and the incidence of stress fractures found is reported in this study.

MATERIAL

A group of 295 new male infantry recruits between the ages of 18 and 20 were evaluated during 14 weeks of basic training in a prospective study of stress fractures beginning in 1983. All of the participants in the study gave their informed consent and knew the goals of the study.

Each of the recruits had a prebasic training screening that included an orthopedic examination. All measurements were done bilaterally. Measurements of joint motion were done according to the guidelines of the American Academy of Orthopaedic Surgeons (AAOS).[8] The other measurements were made according to standard orthopedic texts.[9,15] In the examination the following measurements were made: the range of internal and external rotation of the hip with the hip flexed to 90°; dorsiflexion and plantar flexion of the ankle with the knee in 90° of flexion; hindfoot inversion and eversion from the zero starting position when the heel is aligned with the midline of the tibia; and tibial torsion. Additionally, the presence of genu varum or valgum was noted and gait classified as intoeing, normal, or out-toeing. Ligamentous laxity was classified as below average, average, or above average by the thumb extension laxity test. Each recruit's weight and height was recorded.

The recruits were followed during the course of their training by three army doctors in the field and a hospital-based orthopedist. All recruits were encouraged to report symptoms of possible stress fractures. They had free access to the medical staff as well as mandatory examinations every three weeks during training. Soldiers with symptoms suggesting stress fractures rested for three days and, if symptoms persisted, were seen by an orthopedic surgeon and treated appropriately.

The location of any pain was recorded and its distance from anatomic landmarks measured. Appropriate roentgenograms were taken and late phase Tc^{99} methylene diphosphonate (MDP) scintigraphy of the whole body performed, plus spot views of the feet, tibias, knees, and femurs. A diagnosis of stress fracture was made on the basis of either positive roentgenograms or a positive scintigram; scintigraphic evidence was accepted even if roentgenograms showed no stress fracture, as reported in the earlier studies of Prather *et al.*[13] and Greaney *et al.*[7] The scintigraphy was considered diagnostic of a stress fracture when a focal area of increased uptake was found in the absence of other bony pathology.[13] The time of fracture was considered to coincide with the earliest manifestation of pain in the affected limb.

An orthopedic surgeon reviewed all of the recruits once again at the end of their basic training. They were questioned again as to whether they had had any symptoms suggesting stress fracture, and an orthopedic examination was repeated.

A standard evaluation form for data collection was designed before the study was started. All data was processed through the I.B.M. computer facilities of the Israeli Defense Forces Medical Corps. Statistics were calculated with the Statistical Package for the Social Sciences (SPSS) and the Statistical Analysis System (SAS).

All the variables were tested with the Kolmogorov-Smirnov test and the boxplot test[3] and were found to be asymmetric and not normally distributed ($p = 0.001$). Therefore statistics based on normality (such as *t*-test and multivariate analysis of variance) were not used, and instead nonparametric statistical tests were used in the analysis. Associations between anthropomorphic measurements and stress fractures were examined using the ranks of the variables instead of the original values, using the stepwise logistic regression tests. Wilcoxon rank-sum tests were used to examine differences in each of the variables between subjects with and without stress fractures. The chi-square test was used to examine differences of stress fracture morbidity among soldiers with high and low ranges of motion of external rotation of the hip joint.

RESULTS

During the course of 14 weeks of training, 171 of the 295 recruits in training had scintigrams because of clinical suspicion of stress fracture. On the basis of scintigraphy, 91 of the 295 recruits in training (31%) had stress fractures. A total of 184 stress fractures were found in the 91 recruits. Fifty-five percent of the stress fractures were in the tibias, 34% in the femurs, 9% in the tarsus or metatarsus, and 1% in the pelvis; there were no stress fractures of the calcaneus or femoral neck.

Using the Wilcoxon rank-sum test only, external rotation of the hip was found to have a statistical significance when recruits with and without stress fractures were compared. This relationship was significant when all types of stress fractures were considered together ($p = 0.0163$) and for tibial stress fractures ($p = 0.0345$), but not for femoral stress fractures.

When examining all the variables with the stepwise logistic regression procedure, only external rotation of the hip was found to have a statistically significant association with stress fractures. This association was significant for total stress fractures ($p = 0.02340$) and for tibial stress fractures ($p = 0.03730$), but not for femoral stress fractures.

The variable of external rotation of the hip was subdivided into intervals and the best cutoff point between a high and a low stress fracture incidence group calculated at 65°. Recruits with hip external rotations ≥65° had a higher incidence of stress fractures than those with hip external rotations <65°. Table 1 shows that this relationship was statistically significant (chi-square) for femoral and tibial stress fractures as well as total stress fractures.

TABLE 1. Correlation Between Hip External Rotation and the Incidence of Stress Fractures*

Number of Soldiers	*Hip external rotation* ≥65 *Degrees*	<65 *Degrees*	*Total*	*Significance by* X^2
With femoral stress fractures (%)	19 (22.6)	19 (9.6)	38 (13.5)	$p < 0.01$
With tibial stress fractures (%)	27 (32.1)	31 (15.7)	58 (20.6)	$p < 0.005$
With any type of stress fracture (%)	37 (44.0)	49 (24.7)	86 (30.5)	$p < 0.005$

* External rotation of the hip was measured in 282 of the 295 recruits (95.6%).

The incidence of stress fractures was 1.8 times higher in the high hip external rotation group than in the low hip external rotation group (44% *versus* 25%). The incidence of tibial stress fractures was 2.0 times higher and the incidence of femoral stress fractures 2.4 times higher in the high hip external rotation group than in the low hip external rotation group. Internal rotation of the hip and total internal plus external rotation of the hip were not found to have a statistically significant correlation with the incidence of stress fractures.

DISCUSSION

The orthopedic literature is replete with reports about stress fractures. Their etiology is generally theorized to be a repetitive cyclical overload of bone, in which the reparative capacity of the bone is exceeded.[4] As in any material subjected to cyclical overload, microfailure of the material is a function of both the type of cyclical overloading and the physical properties of the material tested. For a biologic material such as bone, there is additionally the interplay of the reparative capacity of the bone.

Factors related to cyclical overloading of bone and their effect on the incidence of stress fractures have been studied. Hard running surfaces, army boots, and progressive types of training have been implicated as related to the incidence of stress fractures.[10] However, a recent study of two groups of infantry soldiers participating in the same basic training on the same base, but differing only in the cumulative mileage marched, showed no difference in the incidence of stress fractures.[5]

Studies of the relationship between intrinsic anatomic characteristics of trainees and the incidence of stress fractures are limited. In a review of the literature, the authors were unable to find a prospective study that identified an anatomic or physiologic factor among trainees that related to the incidence of stress fractures. Some noncorrelations such as the work of Mustajoki *et al.*[12] exist in which previous participation in sport and aerobic fitness did not correlate with the incidence of stress fractures.

The identification in this study of hip external rotation as a predictor of risk to stress fractures is important. By a simple and easily reproducible measurement, recruits can be screened prior to training and can be divided into groups at high and low risk to stress fracture on the basis of their hip external rotation. Those with external rotations ≥65° are in the high-risk group and those with external rotation <65° are in the low-risk group. The data presented is based on the mean external rotation of both hips, but statistical analysis showed that classification into risk groups on the basis of the external rotation of either the right or left hip alone was just as valid.

Several hypotheses about why recruits with external rotation ≥ 65° had an increased incidence of stress fractures can be made: they

TABLE 2. Normal Range of Hip Internal and External Rotation in Male Subjects with Hip Flexed to 90°

Comparison of Estimated Ranges of Motion (°)			
Hip joint	This study	Boone and Azen[1]	AAOS*
External rotation ± SD	57.0 ± 9.3	50.5 ± 6.1	45
Internal rotation ± SD	52.7 ± 11.4	50.3 ± 6.1	45

* Averages of estimates from four sources used by the American Academy of Orthopaedic Surgeons.[8]

can represent a population with retroverted hips; with increased joint laxity; with a different gait pattern; or with different collagen characteristics in their bone.

The scope of this study was limited to possible identification of predictors of risk for stress fractures. Explanation as to why external rotation of the hip can predict risk to stress fractures cannot be made without further investigation. The data from this study, however, would seem to rule out joint laxity as the mechanism. The group with hip external rotation of ≥65° had neither increased joint laxity as accessed by the thumb extension test nor was the total range of motion of their subtalar, ankle, and hip joints greater than the group whose hip external rotation was <65°.

Table 2 compares the mean value for hip internal and external rotation found in this study with other published data. All measurements were done with the hip flexed to 90°. This study's mean values are higher than those of Boone and Azen,[1] which are from a male population age 18 months to 19 years and are higher than the AAOS data, which is averaged from four sources. These data suggest that, when compared to the American male population, the Israeli army has a larger subpopulation with hip external rotation ≥65°. The existence of a larger subpopulation that is at high risk to stress fractures may partially explain the higher incidence of stress fractures when the Israeli army is compared to the American army.

ACKNOWLEDGMENT

The authors thank V. H. Frankel, M.D. and M. Zeide, M.D. for help in preparing this manuscript.

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