INJURY SIMULATION IN FEMALE GYMNASTS

Harcharan Singh Ranu

College of Medicine, Department of Orthoaedics, King Saud University, Riyadh 11433 Saudi Arabia and American Orthopaedic Biomechanics Research Institute, Atlanta, GA 31139-1441. U.S.A.

INTRODUCTION

Gymnastics, as an activity sport, is over 2000 years old but as a competitive sport it is a little more than 100 years old. The first competition in Olympics was the 1896 in Athens, Greece. An injury rate of 20 % for all sports related to jumping e.g., basketball, skiing and gymnasting (Garrick and Requa, 1). Injury other than falls results in approximately 18,000 deaths in the United States (National Safety Council, 2). Female gymnasts often place un-physiological extreme repetitive loading on their bodies during the common maneuvers characteristic of this sport. Thus, it is necessity to provide quantitative and qualitative analyses of impact behaviors of the feet of gymnasts. The response of fracture or injury due to jumping or landing is also important in designing safety equipment related to sports. A linear elastic fracture mechanics approach has been used for this analysis.

MATERIALS AND METHODS

Five female gymnasts, age 17-21 years, mean weight 565 N, performed a handspring vault landing on a force plate (Fig. 1). Their consent and other research guide lines were followed as required by IRB approval. Vertical ground reaction force was 10.8 times body weight. Cycles to cause failure of bone due to repetitive landings were obtained by using equations: crack growth model was taken as $a_o + \sum_i \Delta a_i$ (1) Where a_o was initial plan size and a_i, crack growth increment associated with i^{th} applied load and process continued until a terminal flaw size was obtained. Numerical model provided a functional relationship between the crack growth rate da/dN and the stress intensity factor range ΔK, i.e., $da/dN = C(\Delta K)^m$ (2) as proposed by Paris and Erdogan [3]. Where a was crack length, N was the number of cycles and C and m were material constants that characterize crack propagation rate. From Equation 2 one obtained cycles of repetitious landings to cause failure (N_f) of bone as:

$$N_f = \int_{a_i}^{a_f} \frac{da}{C \Delta K} \quad (3)$$

where, a_i and a_f are initial and final crack lengths. Using a_i=10.0x10^{-8}, C=1.0 x 10^{-8}, m =1.25, ΔK = 1.12 ($\Delta\sigma$), $\Delta\sigma$ measured stress, Equation (3) was integrated numerically with an increment of 10 x 10^{-6} m to the final value of the crack length (a_f) 10 x 10^{-6} m. Hence rate of change of crack length with number of cycles (da/dN).

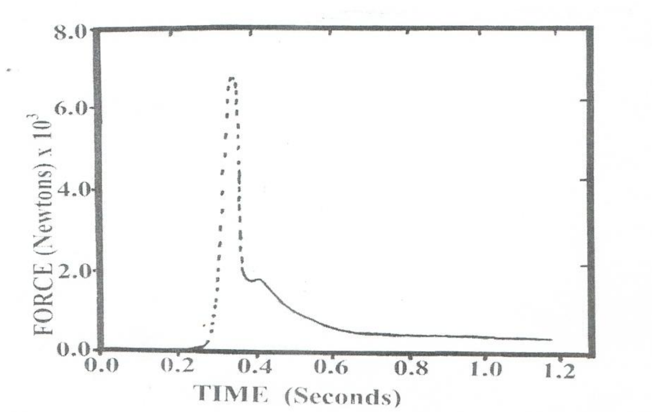

Fig. 1. Vertical ground reaction force (kN) VS Time (Sec.) for a 21 year old female gymnast.

RESULTS

Crack growth rate for a force of F= 6.1 KN and m being 1.25, revealed 6 landings initiated micro-fracture of bone. Number of landings for micro-fracture in bone decreased as value of m increased Fig. 2. Figure 3 shows the crack length (a) against cycles of repetitive jumps (N_f) for different values of m. Crack length increases as the value of m increases.

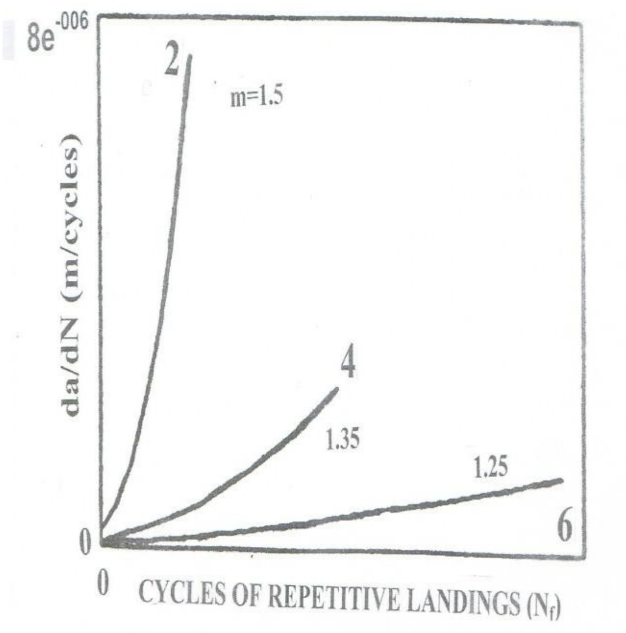

Fig. 2. FCPR against elapsed number of cycles for values of m.

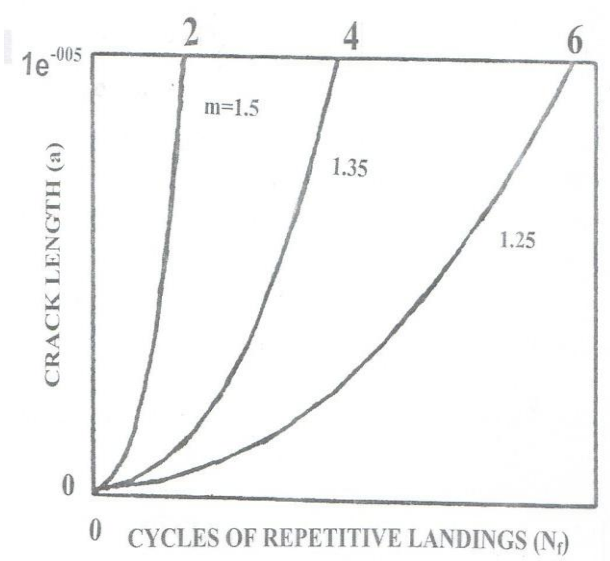

Fig. 3. Crack length (a) against cycles of repetitive jumps (N_f) for values of m.

DISCUSSION

For the first time an *in vivo* stress-fractures are predicted using the laws as suggested by Paris and Erdogan [3] in Gymnasts. It should be remembered that human body is a very complex structure and very much dependent on time as a variable. So computational mechanics is not easy to apply but it does help to predict the unthinkable.

CONCLUSIONS

Data predicted an *in vivo* stress-fractures in gymnasts even before it occurred. It revealed that micro-fracture due to landing was sensitive to number of landings. Magnitude of m is inversely proportional to strength of bone. Model was of significance in computational aspects of bone remodeling, and fracture fixation of bone.

REFERENCES

[1] Gerrick, J., and Requa, R. "Injuries n High School Sports". Paediatrics, **61,** pp 465-469, 1978.

[2] National Safety Council Report, 1972.

[3] Paris, P.C., and Erdogan, F. "A Critical Analysis of Crack Propagation Laws". Trans. ASME, J.Basic Engg. **5**, pp 528-534, 1963.