THE RULE OF CREEP IN THE SEX DIFFERENCES OF LONG BONE RESISTANCE TO FATIGUE FAILURE

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INTRODUCTION

Stress fractures can be caused by prolonged exercise and are associated to cyclic loading. Fatigue is the accumulated damage that results from cyclic loading. This is of special concern for athletes and army recruits. Existing literature shows that the rates of stress fracture for female athletes and army recruits are higher than for their male counterparts [1].

In this study we used an ex-vivo rat model to investigate the fatigue response of female and male rat bones.

METHODS

In this model, 16 weeks old Sprague-Dawley rats were used. Fresh excised tibias were loaded at different strains from 0.5% to 1% ε to determine the strain versus cycles to failure curve (S/N curve) and endurance limit at the physiological frequency of 2Hz.

The tibias were loaded in three-point bending under load control on the medial side, using a servo-hydraulic material testing machine (Instron 8511) equipped with a 220N load cell. Displacement was measured by means of an external high precision LVDT with 10mm travel. The gauge length was 32 mm, and it was kept constant for male and female bones. Strain was calculated from the individual cross sectional dimensions directly measured with calipers at the point of striker contact. Bones were wrapped in gauze continuously soaked with saline and kept moist for the duration of the test. Using MATLAB® the individual cycle data was fitted using the least-squares method. The tangent stiffness was determined by the slope of the line that passes through the minimum and maximum points of the hysterisis curve.

To study the creep behavior, the accumulated strains from each cycle was plotted versus time. The data fitted a characteristic creep curve, with an initial fast creep followed by a steady-state deformation and a subsequent tertiary creep, followed by sudden failure. The strain damage rate was determined by the slope of the line that best fit the steady-state region of the creep data. Strain-to-failure was defined as the maximum strain the bone undergoes before fracture. The statistical analysis was done using SPSS software.

RESULTS AND DISCUSSION

The fatigue data revealed that for the same strain level the endurance limit of the female bones is 20% lower than the males. It has been suggested that the high levels of stress fracture among athletic women occur because their bones are subjected to higher strains [1]. This study shows that even if female bones are subjected to the same strains as males the female bones are still at higher risk of stress fracture.

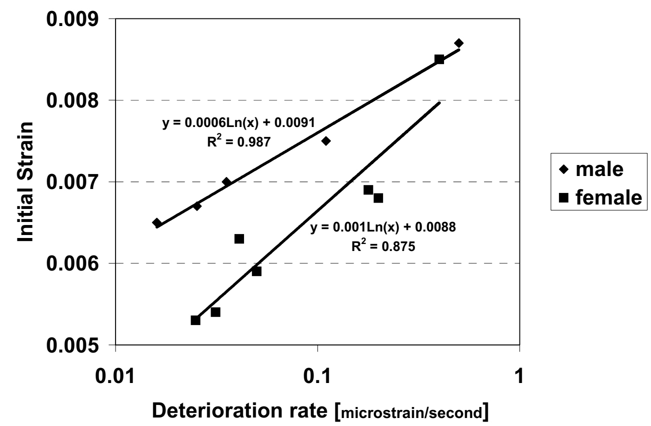

Figure 1:Plot of strain versus deterioration rate for male and female rat tibia

The creep data revealed that the strain-to-failure is similar for both genders; it seems that there is a maximum strain limit before bone fractures. However the higher deterioration rate of the female bones versus strain data (Figure 1), indicate that female bones reach this critical strain at a faster rate than male bones.

CONCLUSIONS

From this study we learned that independently from muscular of biological body response, female bones stressed to the same strain levels as male bones over a period of time, are more likely to experience stress fracture.

In the context of our study, we concluded that the female whole 'bone material' is relatively weaker, i.e. has a lower fatigue resistance than male bone material. For a given initial strain, the deterioration rate was higher for female than male bones. Hence we concluded that the fatigue life of the tibia might be determined by how fast the bone deteriorates.

This study suggests that less intensive exercises may not be enough to address the fast deterioration rate of female bones. Hence, shorter training sessions or frequent training interruptions may allow bone creep relaxation, which may prolong bone fatigue life. This may reduce the rates of stress fractures within female athletes and army recruits.

REFERENCES

1. Burr DB and C. Milgrom. CRC Series in Exercise Physiology. *Musculoskeletal Fatigue and Stress Fractures. 2001.*