INTRODUCTION

It is well established that mechanical loading controls the longitudinal bone growth (Pauwels, 1965). Previous studies with a clinical intention of bone lengthening confirmed an adaptation of the growth plate to static loading. But there is limited information about the effect of dynamic loading through exercise on the growth plate. There are occasional studies which demonstrated a morphological adaptation (Nyska et al., 1995; Swissa-Sivan et al., 1989).

The purpose of the present study was to investigate the age- and dose-dependent alterations of the morphological, biochemical and mechanical properties of the plate to physical loading.

METHODS

Ninety 3 weeks old female Sprague-Dawley rats were randomly assigned to a high trained (HT; n = 30), a low trained (LT; n = 30) and a non-active control group (C; n = 30). The exercise groups were trained in a running wheel with voluntary exercise. Food and water was available ad libitum and the rats housed on a 12 h/12 h light/dark cycle. 10 animals of each group were sacrificed after four weeks, the next ten after eight weeks and the last ten after 12 weeks. The rats were decapitated and the femurs were obtained. The distal epiphysis of the right femur was fixed in Bouin solution, decalcified in EDTA for four weeks and blocked in paraffin. Sections of the growth plate were stained with Masson-Goldner and immunohistochemical with antibodies directed against collagen type II, matrilin-3 and osteonectin. Differences in staining patterns were analysed. In addition, we determined the height of the growth plate, the proliferating and hypertrophic zone. The bone metabolism was monitored by measuring the calcium and phosphate concentration and the activity of alkaline phosphatase in blood serum was measured. The bone mineral density (BMD) and the cross-sectional area of the distal femoral epiphysis was determined with pQCT (Stratec XCT Research SA).

The growth plate of the left femur was loaded in shear direction with a material test machine (Zwick 22.5/TN 1S). The load was applied by a c-formed stamp adapted individually to the form of the plate using a 100 N load cell. The specimen were preloaded with 0.5 N at a rate of 0.5 mm/s. Then the growth plate was loaded to failure at a rate of 15 mm/min. We calculated the ultimate shear stress and strain. The tangent modulus was the slope of the linear portion of the stress-strain curve. The secant modulus was measured at 10 % of the ultimate strain and the area under the stress-strain curve was the energy absorbing capability.

RESULTS AND DISCUSSION

After 8 weeks the body mass of the control group was higher than that of the high trained rats. All animals shows a time-dependent and significant increase in body mass between 7 and 11 weeks. Then, the mass of the low trained and control rats reached a plateau. No differences were seen in femur length and mass. After 11 weeks the growth plate as well as proliferation and hypertrophic zone of control rats was higher compared to the trained groups. After 15 weeks it was contrariwise. Age-dependent the growth plate of control group had a lower activity between 11 and 15 weeks, because the height of the plate was significantly decreased (Fig. 1). The ultimate shear stress of the high trained rats increased from 11 to 15 weeks, whereas low trained and control rats have already reached a limit (Fig. 1).

In general, the control group showed a plateau in the adaptation with an age of 11 weeks whereas the growth plate of the high trained group shows a more continuous adaptation. The low trained group demonstrated a medial position in growth plate adaptation between these two groups. It seems that the individual growth plays an important role.

SUMMARY

Our results reveal that mechanical loading through running exercise leads to an age-dependent adaptation of morphological and biochemical as well as mechanical properties of the growth plate.

REFERENCES

Swissa-Sivan, A. et al. (1989). Bone Miner, 7, 91-105