Bone quality in the lumbar spine in high-performance athletes

Abstract Little is known about the influence of high-performance training on the bone quality of the lumbar spine, in particular, the effects on bone mineral density (BMD) in athletes with high weight-bearing demands on the spine. Measurements were therefore performed in internationally top-ranked high-performance athletes of different disciplines (weight lifters, boxers, and endurance-cyclists). The measurements were carried out by dual-energy X-ray absorptiometry, and the results compared with the measurements of 21 age-matched male controls. The BMD of the high-performance weight lifters was greater than that of the controls by 24% (0.252 g/cm²) on the AP view and by 23% (0.200 g/cm²) on the lateral view (P < 0.01), while difference in BMD between the boxers and the controls was +17% (0.174 g/cm²) on the AP view and +19% (0.174 g/cm²) on the lateral view. The BMD of the lumbar spine in all endurance cyclists was lower than that in the controls (AP view −10%, 0.105 g/cm²; lateral view −8%, 0.067 g/cm²; P > 0.05). The results show that training program stressing axial loads of the skeleton may lead to a significant increase of BMD in the lumbar spine of young individuals. Other authors’ findings that the BMD of endurance athletes may decrease are confirmed. Nevertheless the 10% BMD loss of cyclists was surprisingly high.

Key words Bone mineral density · Dual-energy X-ray absorptiometry · High-performance athletes · Osteoporosis treatment · Osteoporosis prevention

Introduction

As osteoporosis and osteoporosis-related fractures lead to both severe reduction of quality of life and tremendous costs to the community [6], various training and rehabilitation programs have been introduced to prevent the disease or to treat patients suffering from osteoporosis [5, 7, 28]. A positive correlation between physical activity and bone mineral density (BMD) was hypothesized previously [25]. Other authors showed that BMD can be improved by physical training within a few months [17]. On the other hand, bone mineral loss in endurance athletes (mainly female long-distance runners) was reported [23, 35]. Hence, to optimize training programs for prevention and treatment of vertebral osteoporosis, more data on the intensity of training are required [25, 26].

We therefore examined the effect of highly demanding training programs on bone quality in internationally top-ranked athletes performing in different disciplines (weight lifting, boxing, and endurance cycling) and correlated the athletes’ values to the BMD of age-matched controls.

Subjects and methods

Forty male athletes, recruited by the German National Training Center (Bundesleistungszentrum, Heidelberg), were included in
the study. They comprised 28 weightlifters (mean age 22.3 ± 3.9 years, mean body weight 89.4 ± 20.5 kg, mean height 173.5 ± 9.1 cm), 6 boxers (mean age 21.5 ± 2.4 years, mean body weight 77.3 ± 3.8 kg, mean height 179.5 ± 3.8 cm), and 6 endurance cyclists (mean age 26 ± 2.2 years, mean body weight 70.2 ± 4.3 kg, mean height 178.2 ± 3.9 cm). All the athletes were internationally top ranked (weightlifters: two Olympic champions, five world champions, two European champions, national league members; boxers: national league members; cyclists: professionals, Tour-de-France participants), and were training under full specific competition-training conditions at the time of measurement. In weight-lifting training the skeleton is exposed to enormous static loads: a ground lift of 305 kg results in a load on the lumbar vertebrae of 22.9 kN [12], and the athletes work with loads of 68 tons per week on average. The boxers’ training, however, is more varied [10]: body and muscle building is as important as training in fighting techniques, swiftness, and endurance [2]. The cyclists, on the other hand, mostly perform pure endurance training [3]. In the pre-competition period they cover distances of 3,000–10,000 km in low and middle gears [20].

As BMD reference values are not available for all age groups, we established a data base on 21 male controls (mean age 24 ± 1.8 years, mean body weight 73.6 ± 11.1 kg, mean height 178.7 ± 6.4 cm, mixed-discipline sports activity 2.4 h per week).

Qualifications and current health status of athletes and controls were registered on a questionnaire. Only individuals without severe injury or other cause for breaking off training over the 6 weeks immediately preceding the measurements were included in this study.

Prior to the measurements, routine quality control was carried out using an anthropomorphic spine phantom (spine phantom 1179, Hologic) to check the precision of the measuring technique. Informed consent was obtained from all subjects and controls.

BMD was measured with a “second-generation” dual-energy X-ray absorptiometry (DEXA) device (QDR 2000, Siemens) using a high-resolution array scan. The measurements were evaluated with an interactive software program (Hologic). As scientific discussion concerning the most meaningful, precise, and sensitive technique and view is still in progress [11, 31], measurements from both the AP and lateral view of the lumbar spine and the proximal femur were performed. On the AP view of the lumbar spine, L1–L4 is depicted; however, the lateral view is restricted to L2–L4 because of occlusion by the ribs [27]. In elderly individuals L4 may be difficult to evaluate correctly because of overlay by the pelvis. The lateral view enables us to evaluate the whole vertebral body with its cortical frame (LAT value) or a central region of interest (ROI) covering the cancellous bone only (MID value).

The results of BMD measurements were expressed in units of grams per square centimeter. Normal distribution was assessed by Kolmogorov-Smirnov-test. The results are expressed as a mean with standard deviation. For statistical difference testing, unpaired Student’s t-test was used. The level of statistical significance used in this study was \( P < 0.05 \).

**Results**

**Quality control**

Between January 1993 and July 1994, 177 high-resolution array scans of the spine phantom were performed. The average BMD value of the spine phantom was 1.046 ± 0.005 g/cm². The coefficient of variation (cV) was 0.47% (Fig. 1).

**Control individuals**

The BMD values of the lumbar spine of our controls were lower than the values of the preinstalled software kit, which was based on 3,000 North Americans. The mean control BMD in L1–L4 was 93.9 ± 10.9% of the mean value on the preinstalled data base. A statistical difference in the BMD of the lumbar spine is assumed \( P < 0.05 \), as the 95% confidence limits of our control measurements did not reach the 100% line of the references (Fig. 2). Statistical analysis was not performed, as the reference data of Hologic is not accessible.

**Body mass index (BMI)**

The body mass index (BMI), calculated as weight/height² [24], was correlated with the BMD of the lumbar spine. In