Radiographic Changes in the Lumbar Spine in Former Elite Athletes

Holger Schmitt, MD, Emilija Dubljanin, MD, Sven Schneider, PhD, and Marcus Schiltenwolf, MD

Study Design. The authors conducted a retrospective cohort study.

Objective. The objective of this study was to clarify the occurrence of radiographic changes (vertebral osteophytes, heights of lumbar discs, concavity index) of the lumbar spine in former elite athletes of different track and field disciplines.

Summary of Background Data. The influence of physical activity on occurrence of radiographic changes in the lumbar spine is not well known and seems to be contradictory. The loadings in the different track and field disciplines seem to play an important role in the development of radiographic changes.

Methods. One hundred fifty-nine former male elite track and field athletes were selected for a radiologic study. The heights of lumbar discs, the concavity index, the presence of anterior vertebral osteophytes, a radiographic evaluation according to Kellgren and Lawrence, and the FFBH-R score for the assessment of functional limitations in activities of daily living (ADLs) were determined. The influence of age, body mass index, current physical activity, and training history was also examined.

Results. In high jumpers and throwers, the absolute heights of lumbar discs increased from level T12/L1 to a maximum at L4/L5 and decreased again from level L4/L5–L5/S1. In endurance athletes and other jumpers, the absolute heights increased linearly from level T12/L1 to a maximum at L5/S1. The concavity index did not yield any significant differences between athlete categories. Shot putters, discus throwers, and high jumpers showed a significantly higher prevalence of osteophytes after adjustment for possible confounders. According to Kellgren and Lawrence, the highest prevalence of radiographic changes in the lumbar spine is seen in javelin throwers. Significant differences in the assessment of functional limitations in ADLs are not found between the disciplines.

Conclusion. In throwing disciplines, the lumbar spine is more highly loaded than in jumpers and runners. Despite the observation of evident degenerative changes in some former athletes, there were only minor changes seen in ADLs. Even if body constitution is taken as a preselection factor, athletes in throwing disciplines as well as high jumpers have a higher risk of developing vertebral osteophytes of the lumbar spine.

Key words: athletes, radiographic changes, lumbar spine, osteophytes. Spine 2004;29:2554–2559

Heavy physical work can lead to degenerative changes of the spine.1–3 The spines of athletes are subject to frequent and considerable loads, particularly in more vigorous sports. In comparison to nonathletic controls, more radiologic abnormalities of the lumbar spine were found among former elite athletes (age 27–39 years)5 from various types of sports (wrestling, soccer, tennis, and gymnastics). In contrast, Jones showed a similar prevalence of radiographic lumbar spine abnormalities in football players compared with age-matched control subjects.5

No existing studies have dealt with radiographic changes of the lumbar spine many years after termination of an active sports career in track and field disciplines. This study wants to isolate the effect of a specific unusual mechanical loading in different track and field disciplines (throwers, jumpers, endurance athletes). Mechanical loading during physical activity seems to be associated with subsequent degenerative changes of the lumbar spine.6,7

The purpose of the study was to compare lumbar spine radiographs of former elite athletes from 7 various track and field disciplines to determine whether there is a higher prevalence of vertebral osteophytes and radiographic changes in throwers, jumpers, or endurance athletes. Furthermore, the influence of age, body mass index (BMI), current physical activity, and training history on radiographic changes of the lumbar spine should be examined. A correlation of data between radiographic signs of degenerative changes in the lumbar spine and functional limitations in activities of daily living (ADLs) was performed.

Materials and Methods

During a 3-year period, 159 former elite track and field athletes were selected for radiologic examination. Inclusion criteria were: top 40 of the Western German Athletics Association’s lists of top performers between 1972 and 1986, male athletes, and no multievent athletes. Seven disciplines were analyzed. We examined 21 (of 40) javelin throwers (personal best [PB] > 71 m), 19 (of 40) discus throwers/shot putters (PB > 60 m respective PB > 19.40 m), 26 (of 40) long/triple jumpers (PB > 7.80 m respective PB > 16.20 m), 42 (of 48) high jumpers (PB > 2.18 m), 29 (of 40) pole vaulters (PB > 5 m), and 22 (of 40) endurance athletes (marathon: PB < 2:20 hours, racewalking PB 20 km < 1:46 hours). The actual number of

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participating athletes in each group given in relation to the total number available are the result of varying willingness to take part in the study on the part of the athletes. Because of equal personal best marks, the gross sample size of the high jumpers was 48. Discus throwers and shot putters were placed together in 1 group as were long and triple jumpers because of similar training programs and frequent participation by 1 athlete in more than 1 discipline during any 1 event.

Age and BMI at time of examination were documented. The profession and current physical activity were listed. Current physical activity was assessed by the average hours per week spent undertaking physical activities since the termination of an active competitive career. Details of medication intake were also requested from subjects. Of the 159 participating athletes, 32 admitted use of anabolic steroids, 45 denied use, and 82 either refused to answer or were not able to answer. However, an analysis of this issue was omitted for reasons of personal data protection.

Plain lateral radiographs of the lumbar spine of 159 former elite athletes were studied. The radiograph beam was focused on L3 with an anode-film distance between 1.0 and 1.2 m. The height of the lumbar discs was measured according to the Leivas-eth protocol (Figure 1);8 the concavity index for each vertebra was calculated for each vertebral body by dividing the “central” vertebral height by the anterior vertebral height (Figure 2). The presence of anterior osteophytes on the lumbar vertebral body was determined by using a score (none or definite) for each of the 6 levels and a descriptive sum-index was calculated (range 0–6). The reproducibility of the measurements of disc height and concavity index as well as age-dependent reference values are described by Shao.9

The presence of degenerative changes of each lumbar vertebra was determined by using the Kellgren and Lawrence Score.10 A descriptive sum-score (T12/L1–L4/L5) was used to correlate the findings.

Grade 1: minimal osteophytosis only.

Grade 2: definite osteophytosis with some sclerosis of anterior part of vertebral plates.

Grade 3: marked osteophytosis and sclerosis of vertebral plates with slight narrowing of disc space.

Grade 4: large osteophytes, marked sclerosis of vertebral plates, and marked narrowing of disc space.

All radiographs were independently assessed by 3 raters at 2 different times (more than 6 weeks), and the inter- and intrarater reliability was determined by the intraclass coefficient (ICC) in pretests. The ICC was found to lie between 0.52 and 0.97. For further statistical analysis, the mode (most frequent value) of the 3 ratings was used. If there were 3 different values, the median value was used. Radiographs were evaluated blindly.

To assess how far the subjects were restricted in ADLs, an analysis was conducted with the aid of the Hannover Functional Ability Questionnaire for measuring back pain-related disability (FFbH-R).11 The FFbH-R is a short, self-administered questionnaire for the assessment of functional limitations in ADLs among patients with musculoskeletal disorders (subjects can choose between yes, yes, but with trouble, no, or with the help of another person to answer 12 questions such as “Can you stand about 30 minutes without a break [e.g., in a queue]?”). Data from various studies indicate that the FFbH-R meets the relevant psychometric criteria of acceptability, reliability, validity, and sensitivity to change.11

The study was approved by the institutional ethical committee of the medical faculty of the University of Heidelberg, Germany.

For all continuous variables, mean and 95% confidence interval (CI) were computed. The data of the outcome variables and the confounders were tested in one-way analysis of variance for differences between the discipline groups. In the case of lopsided distributions, the Kruskall-Wallis H-test was used. Homogeneity of variances was tested using the Levene F test. In addition, the percentage deviation of each disc height from age-dependent reference values was calculated for all athletes.9

Figure 1. The ventral height of the disc is determined by the sum of the distances of corner 4 of the cranial vertebra and the corner 2 of the caudal vertebra from the bisectrix.8

Figure 2. Measurement of concavity index of vertebrae (B/A).
Linear regression analysis was performed to determine the intergroup differences in the outcome parameters “disc height” and “osteofytes score” under control of possible confounders. A 2-tailed $P$ value equal to or less than 0.05 was considered significant. Data analysis was performed with SPSS for Windows 11.0.1 (SPSS Inc., Chicago, IL).

The age, BMI, the personal best, the duration of competitive sports career (CSC in years), the age on termination of CSC, and the current physical activity of all athletes are presented in Table 1. Athletes after termination of active CSC took on mainly white collar positions; no former athletes were involved in work with a particularly high manual labor component. Both the global results of variance analysis and the results of individual tests of confidence intervals show differences between discipline groups for anthropometric data, training data, and degenerative changes. All athletes differ in age and BMI. It is perhaps not surprising that shot putters and discus throwers were found to be significantly heavier (BMI, 31.8 kg/m$^2$; 95% CI, 30.2–33.4) than other athletes, whereas marathon runners were found to have the lowest BMI values (BMI, 22.0 kg/m$^2$; 95% CI, 20.7–23.3; see Table 1).

### Results

A significantly higher rate/prevalence of osteofytes was found in shot putters and discus throwers compared with the other discipline groups (Table 1) in our radiographic examination of lumbar spines according to the criteria for radiographic changes that were used. A further indicator for radiographic changes was the Kellgren-Lawrence score, rated the shot put athletes and discus throwers highest second only to javelin throwers. Javelin throwers have been found to have scores on average of 8.8 (95% CI, 8.2–9.4). In contrast to these radiologic findings, there were, however, no differences found between discipline groups in the subjective assessment of back pain using the FFbH-R questionnaire despite the high point scores for these groups. Only the marathon runners group exceeded the global averages obtained in the FFbH-R with unrestricted ability values (14 × 100/100 points).

The disc heights of the lumbar spine in the different groups are described in Table 2. In high jumpers and throwers, the absolute heights of lumbar discs increased from level T12/L1 to a maximum at L4/L5 and decreased again from level L4/L5–L5/S1. In endurance athletes, pole vaulters, and long and triple jumpers, the absolute heights increased linearly from T12/L1 to a maximum at L5/S1. Significant differences in disc height between the different disciplines were found in level L1/2 and L3/L4 (Table 2). It was observed that javelin throwers (and also long and triple jumpers) had the greatest disc heights, whereas marathon runners had the lowest. For the intervertebral areas L3/L4 and L4/L5, which have enjoyed much attention in previous literature, comparisons were made with age-dependent reference values. Figure 3 shows that marathon runners have lower disc heights than an age-matched normal population.

The concavity index at all levels of the lumbar spine did not show significant differences between the different groups of athletes and for this reason are not given here in table format.

Finally, for those intervertebral areas in which a bivariate significant difference had been found, multiple regression analyses were performed (Table 2: levels L1/2 and L3/L4). Here it could be shown that the bivariate differences between groups remained significant after compensation for possible confounding variables: the highest disc heights were observed in javelin throwers; the lowest in marathon runners (Table 3).

Shot putters, discus throwers, and high jumpers show more osteofytes in the lumbar spine between L2 and L5 than marathon runners ($+3.09; P < 0.0001$; Table 3).
Adjusted for age, BMI, and training history, no significant effects could be found for the variable “discipline chosen by athlete” on either the Kellgren-Lawrence sum scores or on the results of the FFbH-R questionnaire (data not shown).

Discussion
Changes induced by aging lead to alterations in the thickness of intervertebral discs. Some studies have reported a reduction of intervertebral discs, whereas others reported an increase of disc height with age. A reference database with values of age-dependent heights of lumbar discs and concavity index of lumbar discs was established by Shao examining 1240 radiographs of male and female subjects (aged between 20 and 97 years). Comparing the results of our study with the reference database, marathon athletes have lesser disc heights than the reference population; all other disciplines examined in this study have a tendency toward greater disc heights. It could be hypothesized that exercises such as jumping or throwing with strengthening training and sudden impulse pattern of mechanical loading may have positive nutritional effects on the disc by enhancing the transport of small solutes in and out of the disc. In marathon runners, however, frequent high compression loading of the spinal column could be hypothesized to lead to a height reduction in intervertebral discs and therefore competitive running could have a negative effect on the nutrition of the discs.

This article cannot explain these findings because higher loadings are found in throwers. Disc height seems to be influenced by genetic or other unknown factors but less by mechanical forces or models.

Various parameters can lead to an increase or decrease in lumbar disc height. Twomey and Taylor reported an influence of age in the height of intervertebral discs. They suggested that the relative height of lumbar discs increases with age as a result of loss of height of the vertebral body. Frobin also showed that the height of lumbar discs T12-S increases with age. A magnetic resonance image (MRI) analysis has found greater disc heights in an older population. This data supports a model of the spine in which the disc adapts a more concave form as a result of microfracturing of the end plates during adult life. As a result of the limited range of ages of subjects, we were not able to detect a significant influence of age on disc height; however, the regression coefficients did at least point in the right direction (B: +0.004 to +0.006 [mm/yr], P = 0.43 to P = 0.47).

The influence of physical activity on disc height, concavity index, and occurrence of osteophytes is not well known. Greater signs of disc degeneration of the lumbar

Table 1. Continued

<table>
<thead>
<tr>
<th>Arithmetic Mean (95% confidence interval of the mean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long or Triple Jump</td>
</tr>
<tr>
<td>---------------------</td>
</tr>
<tr>
<td>T12/L1 107</td>
</tr>
<tr>
<td>L1/L2 157</td>
</tr>
<tr>
<td>L2/L3 158</td>
</tr>
<tr>
<td>L3/L4 158</td>
</tr>
<tr>
<td>L4/L5 153</td>
</tr>
<tr>
<td>L5/S1 123</td>
</tr>
</tbody>
</table>

Note: values are given as mean and 95% confidence interval of the mean; the confidence interval of the mean allows horizontal comparisons of differences between groups.

*Centimeters.
†Analysis of variance: F, df, P value.

Table 2. Disc Height in Athletes of Different Disciplines

<table>
<thead>
<tr>
<th>Level No.</th>
<th>Total</th>
<th>Marathon</th>
<th>Racewalking</th>
<th>Long or Triple Jump</th>
<th>High Jump</th>
<th>Pole Vault</th>
<th>Javelin</th>
<th>Shot Put or Discus</th>
<th>Group Differences*</th>
</tr>
</thead>
<tbody>
<tr>
<td>T12/L1 107</td>
<td>0.91 (0.86–0.96)</td>
<td>1.5 (1.2–1.9)</td>
<td>0.84 (0.80–0.88)</td>
<td>0.92 (0.84–1.01)</td>
<td>0.89 (0.80–0.98)</td>
<td>0.92 (0.84–1.01)</td>
<td>0.89 (0.80–0.98)</td>
<td>0.92 (0.84–1.01)</td>
<td>0.86 (0.80–0.98)</td>
</tr>
<tr>
<td>L1/L2 157</td>
<td>1.15 (1.11–1.19)</td>
<td>1.19 (1.02–1.36)</td>
<td>1.12 (1.12–1.32)</td>
<td>1.11 (1.04–1.18)</td>
<td>1.08 (1.00–1.16)</td>
<td>1.09 (1.00–1.16)</td>
<td>1.08 (1.00–1.16)</td>
<td>1.09 (1.00–1.16)</td>
<td>1.08 (1.00–1.16)</td>
</tr>
<tr>
<td>L2/L3 158</td>
<td>1.20 (1.04–1.36)</td>
<td>1.28 (1.10–1.66)</td>
<td>1.08 (1.00–1.16)</td>
<td>1.06 (1.00–1.16)</td>
<td>1.07 (1.00–1.16)</td>
<td>1.08 (1.00–1.16)</td>
<td>1.07 (1.00–1.16)</td>
<td>1.08 (1.00–1.16)</td>
<td>1.07 (1.00–1.16)</td>
</tr>
<tr>
<td>L3/L4 158</td>
<td>1.41 (1.33–1.51)</td>
<td>1.49 (1.32–1.66)</td>
<td>1.52 (1.40–1.65)</td>
<td>1.50 (1.40–1.65)</td>
<td>1.51 (1.40–1.65)</td>
<td>1.52 (1.40–1.65)</td>
<td>1.50 (1.40–1.65)</td>
<td>1.51 (1.40–1.65)</td>
<td>1.50 (1.40–1.65)</td>
</tr>
<tr>
<td>L4/L5 153</td>
<td>1.61 (1.56–1.67)</td>
<td>1.63 (1.48–1.76)</td>
<td>1.62 (1.46–1.77)</td>
<td>1.64 (1.48–1.74)</td>
<td>1.65 (1.49–1.68)</td>
<td>1.63 (1.49–1.68)</td>
<td>1.64 (1.48–1.74)</td>
<td>1.65 (1.49–1.68)</td>
<td>1.64 (1.48–1.74)</td>
</tr>
<tr>
<td>L5/S1 123</td>
<td>1.57 (1.48–1.67)</td>
<td>1.65 (1.41–1.89)</td>
<td>1.67 (1.41–1.89)</td>
<td>1.65 (1.41–1.89)</td>
<td>1.67 (1.41–1.89)</td>
<td>1.66 (1.41–1.89)</td>
<td>1.65 (1.41–1.89)</td>
<td>1.67 (1.41–1.89)</td>
<td>1.66 (1.41–1.89)</td>
</tr>
</tbody>
</table>
spine could be demonstrated in weight lifters and in the lower lumbar spine in soccer players as compared with runners and shooters. Disc height reduction of more than 50% in 1 level of the lumbar spine was documented in 8 of 13 former elite weight lifters, explained by the extreme axial loading of the spine while lifting. Another study showed more radiographic abnormalities (MRI) in gymnasts than in swimmers. In reinforcement workers and house painters, the disc height of the lumbar spine increases from L1 to a maximum at L5 and decreases in the lowest level. Disc space narrowing occurred most frequently in the lowest intervertebral spaces; spondylolytoses were most frequently observed at level L3/4. The changes seem to be more severe at the third lumbar disc because of the greater mobility normally present at this level. In the Finnish identical twin cohort study, Crites Battie could show that disc degeneration may be explained primarily by genetic influences and by some unidentified factors, which may include complex, unpredictable interactions.

In our study, we could state that particularly javelin throwers showed increased lumbar disc heights as compared with runners, even when adjusted for the possible confounders (age, BMI, training history, current physical activity). The low disc height seen at the lowest level of the lumbar spine compared with the upper levels shows the important role of this level in athletes from all throwing disciplines and those competing in high jump. Particularly in throwers, the throwing movements involve extreme hyperextension and rotation of the lumbar spine, so that in young athletes, spondylolisthesis is observed more frequently in throwers than in other athletes. Even in jumping events, the athletes have to bend, extend, and rotate their body, but for the most part in an harmonic movement. It is possible that the patterns of loading experienced by high jumpers during the “Fosbury” flop, i.e., simultaneous rotation and hyperextension, could explain the higher rates of radiographic changes observed as compared with other jumpers. Moreover, in athletic training programs of 20 or more years ago, throwing and jumping athletes participated in a more intensive strengthening training than endurance athletes. Osteophytes in the lowest level are observed more frequently in throwers than in jumpers, endurance athletes, or the normal population.

Vertebral osteophytosis is related to manual labor. Throwers show more osteophytes than runners and jumpers, especially in the lower part of the lumbar spine.

Table 3. Multiple Regression Analyses to Assess Further Influential Factors on Degenerative Changes

<table>
<thead>
<tr>
<th>Disciplines and Confounder</th>
<th>Disc Height Model 1: L1/L2</th>
<th>Disc Height Model 2: L3/L4</th>
<th>Osteophytes Model 3: Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marathon</td>
<td>Reference</td>
<td>Reference</td>
<td>Reference</td>
</tr>
<tr>
<td>Racewalking</td>
<td>0.18</td>
<td>0.37*</td>
<td>1.04</td>
</tr>
<tr>
<td>Long or triple jump</td>
<td>0.24*</td>
<td>0.39†</td>
<td>0.87</td>
</tr>
<tr>
<td>High jump</td>
<td>0.16</td>
<td>0.39†</td>
<td>1.62*</td>
</tr>
<tr>
<td>Pole vault</td>
<td>0.13</td>
<td>0.30*</td>
<td>0.63</td>
</tr>
<tr>
<td>Javelin</td>
<td>0.26†</td>
<td>0.51‡</td>
<td>1.20</td>
</tr>
<tr>
<td>Shot put or discus</td>
<td>0.18</td>
<td>0.27</td>
<td>3.09‡</td>
</tr>
<tr>
<td>Confounder</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.00</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>Body mass index</td>
<td>0.00</td>
<td>0.01</td>
<td>-0.08</td>
</tr>
<tr>
<td>Duration of CSC in years</td>
<td>0.01</td>
<td>0.00</td>
<td>0.09</td>
</tr>
<tr>
<td>Years since termination</td>
<td>0.00</td>
<td>0.00</td>
<td>0.05</td>
</tr>
<tr>
<td>Current physical activity</td>
<td>0.00</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Intercept</td>
<td>0.70*</td>
<td>1.00†</td>
<td>0.50</td>
</tr>
<tr>
<td>r-Square unadjusted</td>
<td>14.3%</td>
<td>15.3%</td>
<td>22.8%</td>
</tr>
<tr>
<td>No.</td>
<td>147</td>
<td>148</td>
<td>131</td>
</tr>
</tbody>
</table>

Note: For “Dependent Variables” linear regression: nonstandardized regression coefficient B for disc heights in millimeters; sum score with range 0–6. <mc>P ≤ 0.05, †P ≤ 0.01, ‡P ≤ 0.001."
Weber and Morgenthaler stated that osteophytes in level L3/4, L4/5, and L5/S1 are equally frequent. In the normal population examined by Shao, osteophytes occurred most frequently at level L4 in men. The influence of special mechanical loading in throwing events on the lumbar spine appears to be proven. In showing that throwers and high jumpers had more vertebral osteophytes than runners and other jumpers, we could support the findings of previous studies that showed that vertebral osteophytosis is related to patterns of heavy loading. Anterior osteophytes are spurs of bone where ligaments are inserted and are a reflection of the physiology of life. Heavy physical loadings with effects of hyperextension and rotation seem to lead to the occurrence of traction spurs. It can be hypothesized that the lower disc level in the lumbar spine in marathon runners is an important preselection factor for different track and field disciplines, throwers and endurance athletes are more likely to be able to perform their sport at a very high level for a longer time than speed strength athletes such as jumpers. The loadings in the different disciplines seem to play an important role in the development of radiographic changes of the lumbar spine. Corresponding to the results of Videman, long-term vigorous running is not deleterious to the spine.

Key Points

- Shot putters, discus throwers, and high jumpers show more vertebral osteophytes in the lumbar spine than other jumpers or runners.
- The level L5/S1 seems to be much more loaded in throwers and jumpers than in endurance athletes.
- Former marathon runners show lower disc height in the lumbar spine than other athletes.

References