

The estimation of lumbar intervertebral disc volumes before and after exercise using the Cavalieri method

Abstract

Purpose: Our aim in this study is to determine the volume differences of the lumbar intervertebral discs by using the Cavalieri method.

Subjects and methods: In our study, lumbar magnetic resonance imaging (MRI) was performed on 20 male (mean age, 22 years; age range, 19–25 years) athletes without any known disease on the lumbar vertebra and discs immediately after resting and after a 50-minute loading exercise.

The lumbar intervertebral disc volumes were measured by Cavalieri method and compared after resting and after exercise. Statistical analyses of the results were carried out to evaluate changes in the disc volume.

Results: The mean volume of the three lower lumbar intervertebral discs (L2-L3, L3-L4, L4-L5) was 17 centimetres cube after resting and 15 centimetres cube after exercise. Total volume decreased from 51 centimetres cube to 45 centimetres cube. After a 50-minute loading exercise, a 12% reduction was detected ($p < 0.05$).

Conclusion: The reduction in the lumbar intervertebral disc volumes after exercise may be useful in providing predictive short-term information through the Cavalieri method.

Keywords: intervertebral disc, disc volume, exercise, cavalieri method, magnetic resonance imaging

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Introduction

Intervertebral discs reduce the harmful effect of the load on the vertebral bodies. The amount of water in the nucleus pulposus plays an important role when intervertebral discs fulfil these functions.^{1,2}

In this study, we aimed to determine the rate of reduction of volume caused by water loss during exercise by Cavalieri method on sectional images obtained by MRI.

Subjects and methods

The study was approved by the Ethics Committee, and written informed consent was obtained from all volunteers before the MR examination. All image evaluations were performed by a radiologist. Each measurement was performed by a single observer.

The standard MR protocol of the spine included sagittal T1-weighted and T2-weighted fast spin echo. Volume measurements are made by using a transparent template to overlay a grid of regularly spaced points over MRI scans of randomly selected patients (Figure 1). This point is counted as the full contact of the counter. Counts are made three times. The double or middle number is used. The volume of an object appearing on a scan (V) is the product of the sum of points that fell on the object ($\sum Pi$), the area associated with each point (ap), and the distance between scan slices (t) in cubic centimetres $\{V = \sum Pi.ap.t\}$.

The lumbar intervertebral disc (L2-L3, L3-L4, and L4-L5) volumes measured after resting and after 50-minute loading exercises were compared. The data were analyzed using SPSS, version 15.0

package program. All statistical tests were set at the 95 % confidence level ($p < 0.05$).

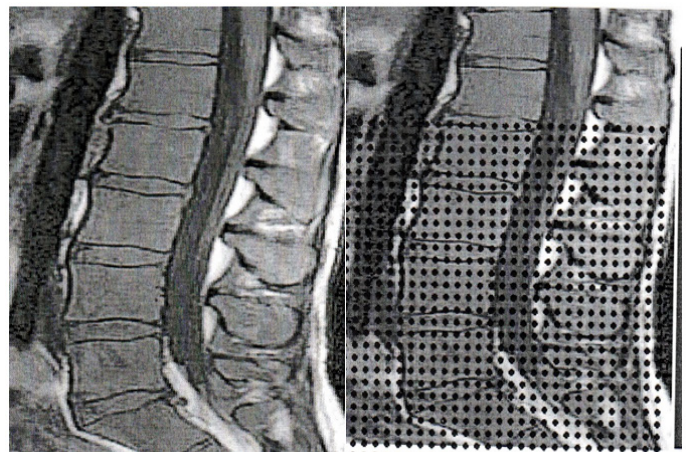


Figure 1 Estimation of the volumes of lumbar intervertebral discs (a) using the Cavalieri method. A transparent square test grid system (2 mm) was superimposed on lumbar discs (b).

Results

The mean and total volumes ($\text{cm}^3 \pm \text{S.D.}$) of three lumbar intervertebral discs are shown in Table 1. The mean CE of the volume estimates was 5%.

The mean volume of the three lumbar intervertebral discs was 17

centimetres cube after resting and 15 centimetres cube after exercise. Total volume decreased from 51 centimetres cube to 45 centimetres cube. After a 50-minute loading exercise, a 12% reduction was detected ($p < 0.05$).

Table 1 The mean and total volumes ($\text{cm}^3 \pm \text{S.D.}$) of three lumbar intervertebral discs

| Lumbar intervertebral discs (L2-L3, L3-L4, L4-L5) | Mean volume | Total volume |
|---|-------------|--------------|
| After resting | 17 \pm 3 | 51 |
| After the loading exercise | 15 \pm 3 | 45 |

Discussion

The nucleus pulposus, which forms a large part of the intervertebral disc, has water-holding properties due to its mucopolysaccharides and proteoglycans.³ Johnstone et al.⁴ have shown that the accumulation of water in the intervertebral discs, due to the decrease in hydrostatic pressure after death, leads to an increase in the volume of the discs.

The volumes of intervertebral discs correlate positively with body height and age. Negative correlation occurs in disk degeneration.⁵ Due to the annulus fibrosus tearing on the disc herniation, the water-holding function of the nucleus pulposus is impaired and consequently, the disc volume may change.⁶

There is a limited number of publications in the literature about whether disc herniation affects spinal ganglia volume at the relevant level and side.⁷ In another study, there was no significant relationship between the presence of disc herniation and spinal ganglion size.⁸

In seven healthy asymptomatic men, Neubert et al.⁹ performed lumbar spine examinations using sagittal T2-weighted fast spin echo images with a 1.5 Tesla MRI scanner before and after exercise. Similar studies to evaluate diurnal variation were also made using T1 relaxation time.¹⁰

Body height increases during rest, depending on the water content in the intervertebral discs. The T2 values of the nucleus pulposus decrease significantly from morning to evening.³ Chokan et al.¹¹ observed a significant decrease in T2 values of nucleus pulposus after exercise. There was a significant increase in T2 values after resting. The same findings were also observed in grade 1 and 2 degenerations of nucleus pulposus.^{3,11-13}

In a retrospective study of 93 patients, a decrease in the volume of degenerated intervertebral discs was detected. In this study, T1-T2 weighted sagittal MR images were examined for volume determination using the Cavalieri method.⁶ Using the Cavalieri principle, volume detection can be done with MR images as well as CT images.^{5,14,15}

In the absence of a CT computer system, the Cavalieri principle was found to be useful in calculating the volume of lumbar intervertebral discs.

In our study, we combined the Cavalieri principle of stereological methods with MRI scanning technique. This technique, which can be quickly applied with a portable transparent template, allows retrospective or prospective studies.^{16,17}

The sum of the points that fell on the object, $\sum Pi$, was then multiplied by the area associated with each point, ap (cm^2), and the distance between slices, t (cm), to arrive at the volumes of related structures and organs, V (cm^3). $\{V = \sum Pi \cdot ap \cdot t\}$.¹⁷

Roberts et al. observed an increase of 1300 cubic millimetres in the lumbar intervertebral disc volumes using Cavalieri's method in MR scans after a normal activity day and at night rest. They concluded

that the increase in the T2-relaxation time of the nucleus pulposus may be due to the increase in water content (2). Botsford et al. found that the mean simulated diurnal volume in the lower three lumbar discs decreased by 16.2% in their studies.¹ Malko et al.¹⁸ observed a 5.4% increase in the volume of L2-L3, L3-L4, and L4-L5 discs after a 3-hour rest (16). Some studies have shown that the total water content in normal lumbar discs decreases by 5-10% at the end of the day.^{18,19}

In our study, we measured volumes of intervertebral discs using Cavalieri method with MRI after resting and after 50 minutes loading exercise. We found a volume reduction of 12% in accordance with the literature.

Conclusion

It may be useful to detect the reduction in the volume of the lumbar intervertebral discs during exercise with the Cavalieri method within a short time.

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None.

Conflict of interest

The author declares no conflict of interest.

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