The Spine Journal 14 (2014) 469–478

Basic Science

Aging changes in lumbar discs and vertebrae and their interaction: a 15-year follow-up study

Tapio Videman, MD, PhD[a,*], Michele C. Battié, PhD[a], Laura E. Gibbons, PhD[b], Kevin Gill, MD[c]

[a]Department of Physical Therapy, Faculty of Rehabilitation Medicine, University of Alberta, 3-44 Corbett Hall, Edmonton, AB, Canada T6G 2G4
[b]General Internal Medicine, Harborview Medical Center , University of Washington, Box 359780, 325 Ninth Ave, Seattle, WA 98104, USA
[c]University of Texas Southwestern Medical Center, Department of Orthopaedic Surgery, 1801 Inwood Road, Dallas, TX 75390 USA

Received 31 January 2013; revised 31 October 2013; accepted 7 November 2013

Abstract

BACKGROUND CONTEXT: Many studies have focused on either the intervertebral disc as a culprit in back pain problems, or the vertebral body, but very few studies have examined both structures and their relationship.

PURPOSE: To measure the concordant changes in morphology of the discs and vertebrae during 5-, 10-, and 15-year follow-ups.

STUDY DESIGN: Longitudinal study.

PATIENT SAMPLE: Among a general population sample of 232 men that had been scanned in 1992–1993, 105 men were reexamined in 1997–1998 and 2007–2008. Mean age at the 15-year follow-up was 63 years. A confirmatory sample with 10 years follow-up was also included.

METHODS: Scanners (1.5 Tesla) with surface coils were used at baseline and follow-up. Image analyzing software was used to measure distances and areas of interest of midsagittal and midaxial spine images.

RESULTS: The disc heights decreased at 5 years by 3.4% (0.4 mm) and 3.3% (0.4 mm) and at 15 years by 8.7% (1.0 mm) and 11.3% (1.3 mm) in the upper and lower discs, respectively ($p<.001$). Although not clear after 5 years, vertebra heights increased in mean by 3.1% (0.8 mm) in the upper lumbar levels and by 4.7% (1.1 mm) in the lower vertebrae after 15 years ($p<.001$). Vertebra height increases were associated with disc narrowing ($p=.001$). The mean annual shortening of the lumbar spine L1–S1 block was 0.13 mm/y, which was in line with the mean standing height that decreased little (174.7 cm at baseline and 174.4 cm at the follow-up).

CONCLUSIONS: Discs and vertebrae degenerate or remodel in concert: decreases in disc height appear to be compensated, in part, by accompanying increases in adjacent vertebra heights. The mechanism behind this novel finding and its implications require further study.

Keywords: Disc degeneration; End plate; Lumbar spine; MRI; Pathology; Vertebra

Introduction

Many studies have focused on either the intervertebral disc, as it is believed by many to be a culprit in back pain problems, or the vertebral body, typically related to osteoporotic fracture or Modic changes, but very few studies have examined both the structures and their relation. Several investigations of lumbar vertebral bone mineral density (BMD) in relation to disc degeneration have been conducted, with most suggesting that higher vertebral BMD is associated with more disc degeneration [1–3]. Analyses of

FDA device/drug status: Not applicable.

Author disclosures: ***TV:*** Nothing to disclose. ***MCB:*** Nothing to disclose. ***LEG:*** Consulting fee or honorarium: University of Alberta (A) ***KG:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

* Corresponding author. Faculty of Rehabilitation Medicine, University of Alberta, 3-44 Corbett Hall, Edmonton, AB T6G 2G4, Canada. Tel.: 780-492-5968; fax: 780-492-1626.

E-mail address: tapio.videman@ualberta.ca (T. Videman)

1529-9430/$ - see front matter
http://dx.doi.org/10.1016/j.spinee.2013.11.018

autopsy material, using estimates of disc degeneration from discography and vertebral BMD from microcomputed tomography, showed more specifically that higher BMD of the vertebral body and greater end plate thickness were associated with more disc degeneration [4]. Based on another study of 27 cadavers, Simpson et al. [5] hypothesized that disc "*disorganization significantly modulates bone degeneration that could influence the incidence of vertebral body crush fracture*." Moore at al [6] found in a study of sheep that "*outer anular injury*" was associated with greater vertebral trabecular bone volume. Overall, these studies suggest an interaction between the degeneration or pathogenesis of discs and vertebrae, but longitudinal studies are needed to clarify these relations and others. A number of investigators have conducted longitudinal studies of disc herniations after surgery, "Modic changes" [7,8], or qualitatively assessed disc degeneration [9]. Yet, we are aware of no longitudinal studies that investigate the concurrent changes in morphology of the discs and vertebrae and their interaction.

Better understanding of pathogenesis has commonly enhanced prevention and led to more rational treatment of underlying illnesses. Our goals were to describe the changes in shape and size of lumbar vertebrae and discs occurring over a 15-year period in a general population sample of men using quantitative magnetic resonance imaging (MRI) measures and visual assessments.

Materials and methods

Subjects

Participants for this study were selected from the 232 monozygotic (MZ) twins initially recruited in the Twin Spine Study, which were drawn from the population-based Finnish twin cohort that included all same-sex twins born in Finland before 1958 and still alive in 1975 [10]. The initial selection of MZ twins, which has been described in detail previously [10], was based on co-twin discordance for one of the common environmental exposures, primarily occupational or leisure physical activities. The MZ subjects in the Twin Spine Study have been shown to be highly representative of the Finnish Twin Cohort, which is representative of the Finnish population [11].

After 5 years, 75 twin pairs were reexamined, with 5 pairs excluded because of steroid medication use [12]. Of the 140 men remaining, 116 were still living and able to travel to the study center to be reexamined again approximately 15 years after their baseline evaluations (range, 14.9–16.7 years). Two subjects were later determined to be dizygotic twins, one was accidentally omitted from the quantitative assessments, and six more were excluded because of errors in the MRI acquisition and two because of unacceptable image quality, leaving 105 men for inclusion in the analyses. The mean age at the time of the final follow-up was 63 years (range, 50–79 years).

A confirmatory sample came from 70 MZ and 296 dizygotic twins recruited approximately 5 years after the initial group of 232 MZ twins using analogous selection criteria as the original MZ sample. Their baseline and follow-up images were obtained approximately 10 years apart. Of the 70 MZ twins, all 47 who were successfully contacted and fit to travel participated and an additional sample of 42 DZ twins was recruited. Because of cases of missing data, the final confirmatory group comprised 87 men. The mean age at the follow-up of the confirmatory group was 60 years (range, 51–77 years).

All subjects received written information about the study procedures before participation and the study protocols were reviewed and approved by the Ethical Committees of the Department of Public Health at the University of Helsinki and the University of Alberta.

MRI data

A 1.5 Tesla scanner with surface coils (Magnetom SP 4000, Siemens AG, Erlangen, Germany) was used at baseline and at the 5-year follow-up, and a Siemens Zebra scanner ("Avanto" with software MR B15) was used at 15-year follow-up. The 87 men in the confirmatory group were imaged with a Siemens Magnetom Vision scanner at baseline and with the Siemens Avanto scanner at the 10-year at follow-up. The field of view was 260 mm, and the slice thickness and interslice gap were 4 mm and 0.4 mm for sagittal images and 3 mm and 0.3 mm for axial slices for the Magnetom. The field of view was 320 mm (in axial, 348×384 mm), and the slice thickness and interslice gap were 4mm and 0.4mm for the sagittal images using the Avanto. The pixel size of the Magnetom images was 1.02 mm and 0.8125 mm for the Avanto. Pixel size differences in baseline and follow-up images were accounted for when converting to millimetres. Each subject was lying supine for 30 to 45 minutes immediately before MRI scanning.

Quantitative MRI measures

Custom image analysis software (SpEx) was used to measure areas of interest on the midsagittal and midaxial spine images. When segmenting the lumbar vertebral bodies and discs on the midsagittal images, one vertical line followed the anterior longitudinal ligament and a second vertical line followed the posterior longitudinal ligament, dividing it from the cerebrospinal fluid space. Horizontal lines were then drawn following the disc and vertebra interface to delineate the areas of interest (Fig. 1, Left). In cases of scoliosis, the midsagittal measurements of each vertebra were obtained from different slices, if necessary. On axial images, positioned separately for each disc at the mid-disc level, the disc was segmented from the surrounding tissues. The segmenting was done on proton density images with verification using T1 and T2 images; T1 images were not available for axial slices. Because the Vision scanner did not have a filter, which affected the magnetic field in the periphery, we measured only the upper lumbar spine (T12–L4) on the 5-year follow-up sagittal images.

The height of each disc was obtained from the midsagittal image by dividing the disc area by its midsagittal diameter.