THE LOAD-BEARING FUNCTION OF APOPHYSEAL JOINTS INCREASES WITH AGE AND DISC DEGENERATION.

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Introduction The role of the apophyseal joints in resisting compressive forces on the spine is important. A moderate load-bearing role could benefit the spine by increasing the compressive strength of the vertebral body-intervertebral disc unit. On the other hand, a large load-bearing role could lead to bone remodelling, ligament stretching, and pain. Previous experiments have shown that the apophyseal joints resist substantial compressive forces only when disc height is reduced by sustained "creep" loading (1). Unfortunately, previous methods used to infer apophyseal joint load-bearing were not accurate, and results were obtained on relatively few specimens. The technique of intervertebral disc "stress profilometry" offers a better and more convenient method of assessing the load-bearing role of the apophyseal joints in a large group of cadaveric spines. Essentially, the distribution of compressive stress within the disc can be used to calculate the overall compressive force acting on the disc, and this is then subtracted from the force applied to the entire motion segment to infer the force passing through the apophyseal joints. This method has been used to accurately measure the load-bearing function of these joints, and to explain how it changes with advancing age. Unfortunately, previous methods used to infer apophyseal joint load-bearing were not accurate, and results were obtained on relatively few specimens. The technique of intervertebral disc "stress profilometry" offers a better and more convenient method of assessing the load-bearing role of the apophyseal joints in a large group of cadaveric spines. Essentially, the distribution of compressive stress within the disc can be used to calculate the overall compressive force acting on the disc, and this is then subtracted from the force applied to the entire motion segment to infer the force passing through the apophyseal joints. This method has been used to accurately measure the load-bearing function of these joints, and to explain how it changes with advancing age and disc degeneration.

Methods Seventeen lumbar spines were obtained postmortem, and stored at –17°C until required for testing. Spines were then dissected into 23 "motion segments" consisting of two vertebrae and the intervening disc and ligaments. All ligamentous tissue was preserved. Each motion segment was secured in two cups of dental plaster, positioned in the desired angle of flexion or extension, and loaded on a computer-controlled hydraulic materials testing machine. A constant load of 1 kN or 2 kN was applied for a period of 20s while a pressure-transducer was pulled through the disc along its mid-sagittal plane. Validation tests have shown that the transducer output within disc tissues is equal to the average compressive stress acting perpendicular to its membrane. Profiles of vertically-acting compressive stress were obtained in each disc in three simulated postures: 2° of extension (appropriate for erect standing), moderate flexion, and the neutral position, (no bending). All measurements were repeated following a period of creep compressive loading which reduced disc height by an amount equivalent to the diurnal variation seen in vivo (1). From each profile, an estimation of the force acting on the intervertebral disc was calculated using a computer program. For this purpose, the disc was imagined to be composed of number of elliptical rings of known cross-sectional area. The force acting on each ring was given by the product of area and the compressive stress acting, which was obtained from the appropriate position within the stress profile. The total force acting was obtained by summing up the force contribution from each ring. A correction factor was obtained to account for the fact that the lumbar discs are not elliptical, and to allow for possible variations in the sensitivity of the transducer in disc tissues of different age. The correction factor was calculated separately for each disc by analysing the stress distribution when the disc is positioned in the neutral position before creep loading: under these circumstances, it is estimated that less than 2% of the compressive force passes through the apophyseal joints. The force calculated by the programme could be compared to the actual applied compressive force acting through the disc. This yielded a correction factor which could then be applied to stress profiles measured after creep loading, in order to calculate the overall force acting on disc. Hence, the force acting on the apophyseal joints could be calculated to an estimated accuracy of 3%.

Results Posture had an influence on the proportion of load transmitted by the apophyseal joints (figure 1). On average, apophyseal joint loading increased 19% in 2° of extension, and fell to 5% when the motion segment was flexed by 0-4°. However, there was a large variation in results. When motion segments were in 2° of extension, load bearing by the apophyseal joints correlated significantly with age (p<0.01, figure 2). On average, load-bearing on the apophyseal joints increased from 7% of the applied compressive force at age 27 yrs to 42% at 82 yrs. Similarly, apophyseal joint load-bearing increased from 8% in non-degenerated "grade 1" discs, to 40% in severely degenerated "grade 4" discs.

Discussion Results show how increasing age causes the apophyseal joints to resist an increasing proportion of the compressive force acting on the lumbar spine. Results are from profiles taken on cadaveric specimens after creep loading, so they are applicable to living people only after they have been out of bed for several hours. The computational technique employed makes a few simplifying assumptions, because it used a correction factor which takes full account of the exact geometric and physical properties of each disc. They only assumption required is that the apophyseal joints resist no compressive force in the neutral posture before creep loading. This was the case in all 27 specimens aged between 25 and 79 yrs which were analysed previously using a different technique (1). It is possible that several of the old specimens with narrowed discs used in the present study might have behaved differently, and that the apophyseal joints did resist some compressive force in the neutral position before creep loading. If that were the case, then the reported values of apophyseal joint load-bearing after creep loading for those particular specimens would be underestimated by a similar amount. Overall, these results highlight the substantial load-bearing role of the apophyseal joints in elderly people. This must be taken into account when assessing spinal strength, and the risk of osteoporotic spinal fractures, in elderly people.

References

Figure 1 Apophyseal joint load-bearing increased by approximately 12% in lordotic posture compared to moderately-flexed posture. Error bars indicate standard deviation. Data obtained after creep loading.

Figure 2 Relation between age and load-bearing by the apophyseal joint at 2° of extension following creep loading.

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