WORKSHEET 2

SPINAL STRESS

1) During lifting a box the compressive force in the lumbar spine was calculated using a mathematical model of the back. The compressive force (Fcomp) was 5000 N. Calculate the average compressive stress at the intervertebral disk:

\[ \text{Force per area} = \frac{F_{\text{comp}}}{A_{\text{disk}}} \]

We can calculate the area of an oval shape (Aoval) as

\[ A_{\text{oval}} = \pi \times a \times b \]

entering numbers: \( A_{\text{oval}} = 0.0018846 \text{ m}^2 \)

The area of the disk (Adisk) is then:

\[ A_{\text{disk}} = A_{\text{oval}} - 10\% (A_{\text{oval}}) \]

execute on calculator: \( A_{\text{disk}} = 0.00169614 \text{ m}^2 \)

The compressive stress/pressure (\( \sigma_{\text{comp}} \)) in this case is calculated simply as the ratio of force per area:

\[ \sigma_{\text{comp}} = \frac{F_{\text{comp}}}{A_{\text{disk}}} \]

entering the numbers gives: \( \sigma_{\text{comp}} = \frac{5000}{0.00169614} \text{ N/m}^2 = 2947869.9 \text{ N/m}^2 \)

\[ = 2.9 \text{ MPa} \]

Remember: 1 Pascal = 1 Pa = 1 N/m\(^2\), 1 kPa = 1000 Pa, 1 MPa = 1 000 000 Pa
We can compare these values to the material properties given in Lecture 3 and find that such a load is uncritical for cartilage. But remember, the intervertebral disk is not ‘made of’ hyaline cartilage. You looked at its ‘construction’ in your anatomy classes. It can sustain higher loads than hyaline cartilage. Still, this example demonstrates how internal stresses can be calculated from external forces. But it is very very important to note that it is quite difficult to get realistic numbers for a given individual ... – Therefore all examples given in these lectures are to be considered estimates.

2) Calculate the stress in/on the nucleus pulposus (NP) and the annulus fibrosus (AF) areas. Consider both as covering half of the cross sectional area of the disk.

![Diagram](image)

This drawing seems a bit confusing (I took it from a medical textbook which aimed at illustrating the mechanical situation in a vertebral disk) as it uses 1.5 times F and 0.5 times F to indicate how the load is shared between the two areas. F is NOT the same as Fcomp given in Question 1. Actually, F in this case has to be read as \( \sigma \) (stress!). This means the average stress calculated in Question 1 by equally distributing the load across the whole area is realized by having 1.5 times the average stress in NP and 0.5 times \( \sigma \)comp in/on AF.

So:

\[
\sigma_{AF} = 0.5 \times \sigma_{comp} \text{ and } \sigma_{NP} = 1.5 \times \sigma_{comp}
\]

entering values gives: \( \sigma_{AF} = 1.47 \text{ MPa} \) and \( \sigma_{NP} = 4.42 \text{ MPa} \)

Additional info:

The drawing shows 5 F in lateral direction. This indicates that the fluid filled NP is compressed like a bucket full of water so the walls of the bucket will bulge outward. In
reality, the disc is much flatter than drawn in this sketch so the outside wall (made up out of crossed fibro-cartilage fibres has to withstand high tensional stress, which is what fibro-cartilage is made for). So, roughly speaking, if the surface area of the wall is 1/5th of Adisk the sideways stress will be 5 times as big as the compressive stress.