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What happens if an arm lock goes too far?

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Abstract
Jiu jitsu is a Japanese martial art which partially looks at locking of limbs and joints to impart pain into an assailant, thus discouraging continued aggression. This paper will be looking at the application of a straight arm lock to see what would occur if it were applied to breaking point.

Introduction
There are many different styles of jiu jitsu , some focussing on competitions, others on practical self defence. The majority of self defence techniques practise joint locking as a means of incapacitating an assailant. The theory being that if a joint, (e.g. the shoulder, wrist, or elbow) is manipulated in a way it was not designed to withstand, this creates pain in the attacker, forcing them to submit. Two ways to do this are: bending the joint beyond its limit of flexibility (Figure 1), or bending it in an undesired direction (Figure 2).

Figure 1 shows a bent wristlock being applied. The wrist (white sleeve) is being hyperextended beyond its normal flexibility to cause pain [1].

Figure 2 shows an armbar. The first jitsuka (in blue) has his elbow pointing towards the second jitsuka's (in white) hips. The second jitsuka is pulling the arm in towards him to bend the elbow the wrong way, causing pain in the arm [2].

This paper looks at what happens if the joint continues to be hyperextended, after submission of the assailant, until breaking point.

Straight Arm Lock
The focus of this paper is on a straight arm lock in which the arm is held straight and pressure is applied to the elbow (figure 3).

Figure 3 shows a diagram of an elbow and where pressure would be applied [3].

Four separate methods of ‘breaking’ will be taken into consideration: breaking of the ulna bone, breaking of the tendons, breaking of the ligaments, and detachment of the tendons or ligaments from the bones. For each of these, pressure will be applied to deduce which of the four will occur first when an arm lock is applied. For this we will need to find out the flexural strength of the ulna bone, the tensile strengths of the distal biceps tendon (figure

4)

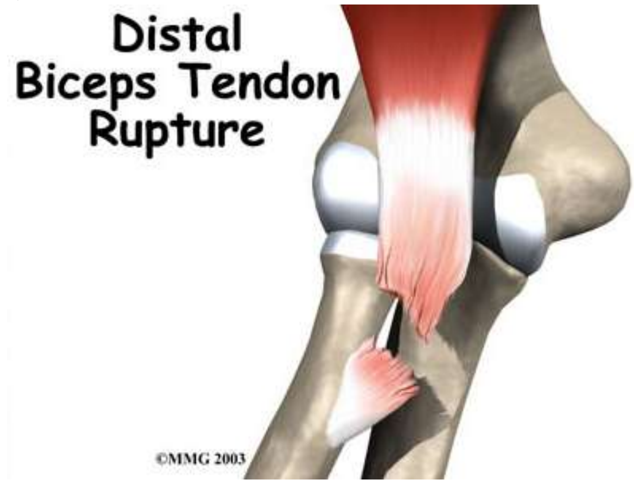

Figure 4 shows a rupture of the distal biceps tendon. Image taken from Samimi B (2013)

the ulnar ligament (figure 5)

Figure 5 shows the UCL (ulnar colateral ligament) and labels the anterior band (the point which would break if the elbow were hyperextended) image taken from Lintner D (2003)

and the fibro-osseous junction: the area where a ligament or tendon attaches to the bone.

Flexural Strength of the Ulna Bone

John Currey showed that the flexural strength of bone was almost linearly proportional to the Young's modulus of elasticity/100. This means that 100 pascals of young's modulus corresponds to 1 pascal of flexural strength [4].

$$Y = \frac{FL_o}{AdL}$$

Equation 1

Where *Y* is Young's modulus of elasticity, *F* is the force applied, L_o is the initial length, *A* is cross sectional area and *dL* is the change in length.

Donald Reilly found the Young's modulus of the femur to be 17 gigapascals (GPa) [5]. If we take the femur to be 0.45 m long with a cross sectional area of 0.002 m^2 [12], we can divide our 17 GPa Young's modulus value by 0.45/0.002 and multiply by 0.32/0.001 where 0.32m is the length of the ulna bone and 0.001m is the cross sectional area of the ulna bone[12]. This returns a value of 24 GPa for *Y*. Dividing 24 by 100 gives us the flexural strength of the ulna bone of 0.24 GPa.

Tensile Strength of the Distal Biceps Tendon

Blanton found the average tensile strength of forearm flexor tendons to be 8700 pounds per square inch [6]. This converts to roughly 0.06 GPa.

Tensile Strength of Ulnar Ligament

Azar found the ultimate tensile strength of the Ulnar Collateral Ligament (UCL) to be 33Nm [7]. If we divide this value by the mean dimensions of the UCL of the elbow, $0.0211\ \mathrm{m} \times 0.0127\ \mathrm{m}$ [8] to get a value in Gigapascals, we get an ultimate tensile strength of 1.23×10^{-4} GPa.

Conclusion

The calculated final values (in GPa) are:

Flexural strength of ulna bone: 0.24

Tensile strength of distal biceps tendon: 0.06

Tensile strength of ulna ligament: 1.23×10^{-4}

Although a value for the tensile strength of the fibro-osseous junction could not be found, multiple sources confirmed that, in cases of tendon and ligament injury, this area was the most common for damage to occur [13][14]. We can therefore assume that when breaking someone's arm the fibro-osseous junction of the ulnar ligament will be the first to give. If pressure to the elbow continues to be applied, the distal biceps tendon will detach from the ulna bone (i.e. it will break at the fibro-osseous junction), before the ulna bone finally breaks.

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