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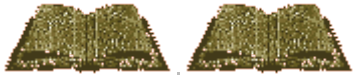
Book Reviews: Technical Books Section



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AN ABSOLUTE MUST FOR ACCIDENT INVESTIGATORS

Biomechanics of Soft-Tissue Injury, 2001 *by* Mark Gomez, Ph.D.
Lawyers and Judges Publishing Company, Inc., P.O. Box 30040, Tucson, AZ 85751-0040, 124 pages, 8 1/2" x 11", casebound, ISBN 0-913875-50-3. $99.00.

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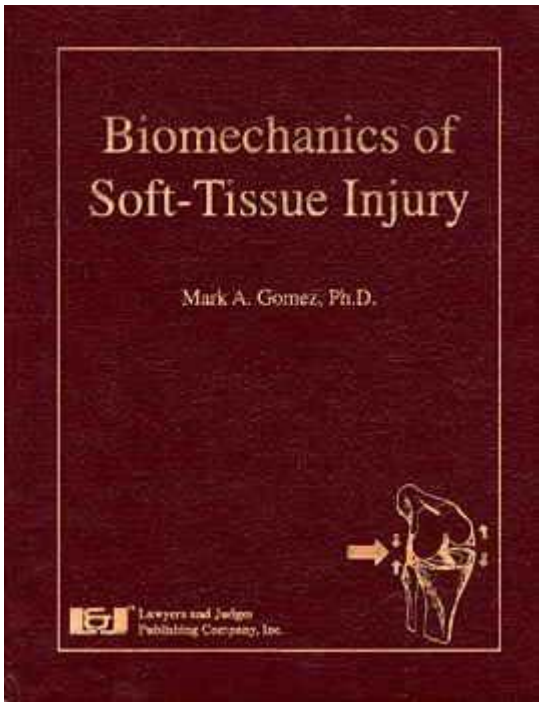


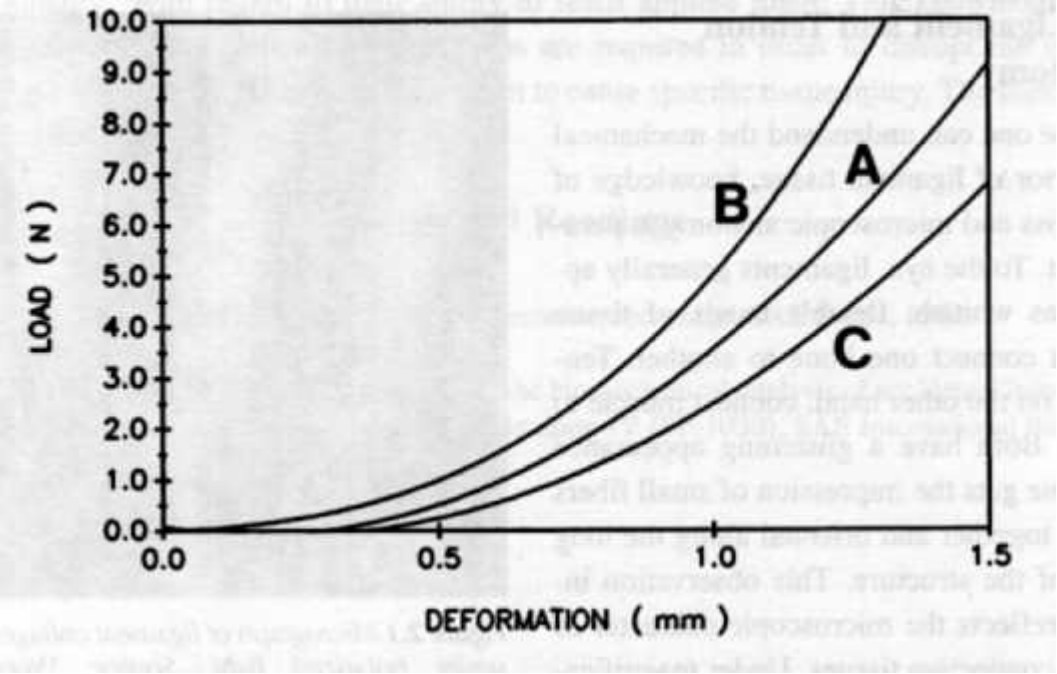
Forensic pathologists are quite well-versed with various forms of injuries and their descriptions, but they may not always be aware of the exact physics involved in producing these injuries. It might appear to many of us that this aspect may be of mere academic importance, but this is not so. The book under review explains very clearly and succinctly how a proper understanding of physical and engineering principles involved in production of injury could work wonders in a court of law, especially in proving or disproving the guilt of a person.

If you are going to turn this page over thinking that physics and engineering is not your cup of tea, wait a minute! This is what I too thought when I first began reading this book. But as I dwelt deep into the book, I realized that the author does not assume very deep knowledge of physics and engineering principles from us. A preliminary understanding of very simple high school physics is expected, and in many cases, even these principles are re-explained quite nicely. For instance, one of the principles which keeps cropping over and over again is the Young's Modulus (the author does not utter this word anywhere, but I presume this is what he is talking about when he talks about Stress and Strain, and muscle and ligament shortening and lengthening). The author explains this principle with ample analogies.

Yes! Analogy is something which is probably the greatest strength of this book. Whenever I stumbled understanding a principle, I was immediately greeted with a simple analogy occurring in every day life, which made reading further on so much simpler. Sample some of the examples given below, and you would understand what I am talking about.

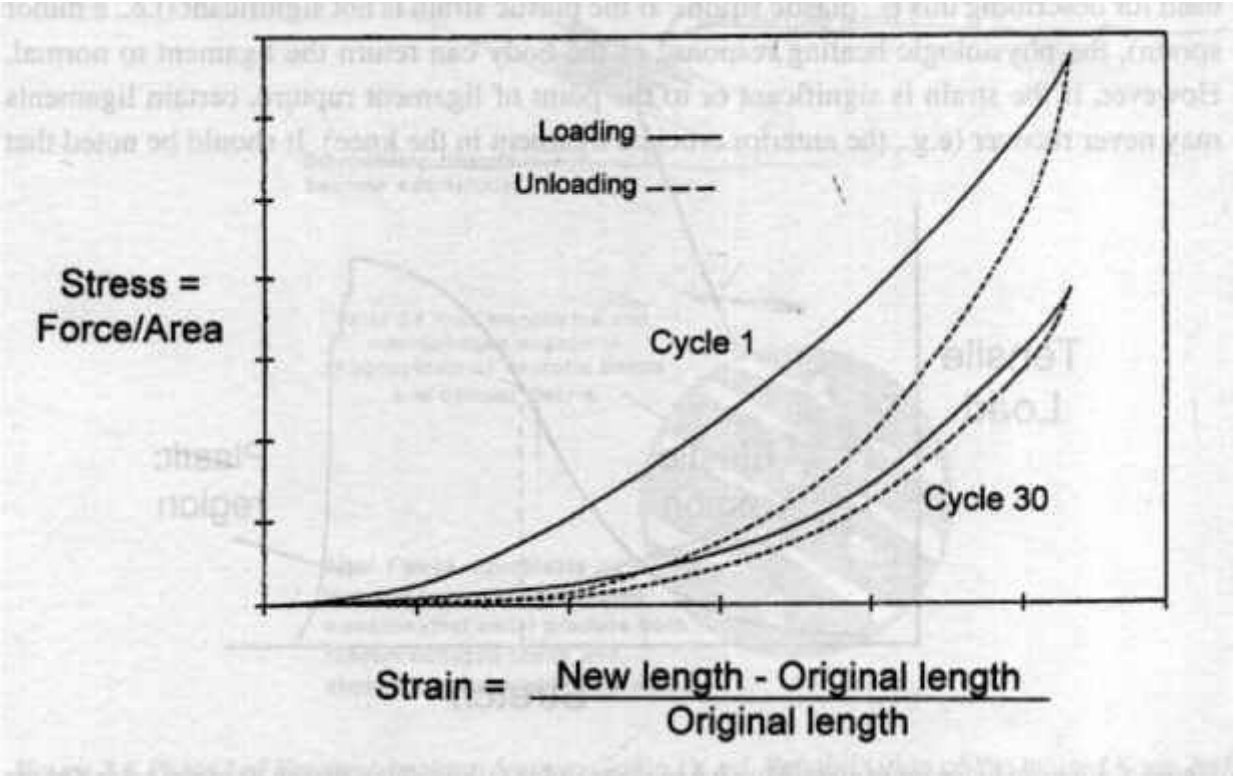
View this book on Amazon

This interesting graph appears on page 10 of the book. Curve A denotes load deformation of a normal ligament. Curve B is produced by a ligament with larger cross section (equivalent to two rubber bands!), and curve C denotes a ligament of longer length (a rubber band of five inches!) - Click picture to enlarge



In chapter two, the author explains us about the biomechanical properties of ligaments, tendons and muscles. These structures are treated as an ordinary mechanical engineer would treat a wire of steel, stretching and straining it under variable loads and studying the resulting changes in length. Biomechanical engineers similarly put stresses and strains on ligaments (and muscles and tendons), and try to understand the forces which would produce tears in them. This helps in interpreting various injuries. At page 10, the author tries to explain us that when a load is put on a ligament, it would stretch. This is quite logical to understand. But further on he tells us that "the resulting load-deformation behavior is nonlinear and depends on the cross-sectional area and the length of the ligament". This may not be a very clear statement to many of us, especially those who have a rather sketchy background in physics. But the author comes to our rescue immediately and explains with a neat analogy. He goes on to say," A simple example would be the load experienced when a person stretches one rubber band versus two rubber bands. It is harder to stretch two rubber bands to a particular distance compared to that encountered while stretching one rubber band." Now this simple analogy tells us the difference between a load put on one tendon and another with twice the cross-sectional area. The string of analogy does not end here. The author further states," Using the rubber band example, it is much simpler to stretch a five-inch-long rubber band one inch than it is to stretch a half-inch-long rubber band the same amount." This tells us the effect seen in ligaments of different lengths!

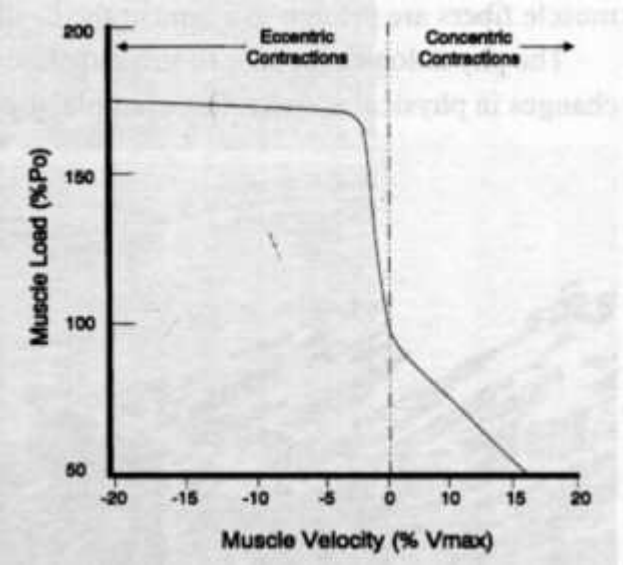
This interesting curve tells you why you like to "stretch" in the morning after getting up (Click picture to enlarge)



The book abounds in such analogies. To be very honest, I would have stopped reading this book at several places, if these analogies had not come to my rescue immediately. And quite interestingly, the author seems to know just where he has to "spring" these analogies. Consider another example. The author is discussing the stress-strain properties of a ligament, when it is strained and then unstrained to a level at which no injury to the ligament takes place. It is like putting a small weight on a wire of steel, letting it lengthen somewhat (without breaking it), and then taking off that weight. The cycle is repeated over and over again. Experimentally it has been found that as the applied strain (l/L where l is the change in length and L is the original length) increases, the stress (F/a where F is the force and a the area of cross-section) goes up in an exponential fashion. If now the strain were to be removed, one would expect the stress to come down "via the same curve". However it does not happen. The stress falls very sharply in the beginning. This can be seen from the adjoining curve which appears on page 11 of the book. However if this cycle of loading and unloading the ligament continues, the stress-strain curves become both repeatable and similar after a finite number of cycles. The adjoining graph shows up these curves at cycle 1 and cycle 30. It is quite clear that at the 30th cycle, the stress-strain curves of both loading and unloading are quite similar. If this strain cycling is discontinued for a period of time, the ligament "recovers", i.e. it would once again show the stress-strain curves seen in cycle 1.

One thing that is very apparent from the above graph is that same stress produces different strains in cycle 1 and cycle 30. During the latter cycles, same stress is able to lengthen the ligaments more. How does this translate into ordinary language? The author comes to our rescue, and gives an everyday example. When a person "stretches" up in the morning to loosen up, quite unknowingly he takes advantage of the accompanying principle. He performs the cycle 1 purposely making the subsequent cycles easier. In other words it becomes much easier subsequently to move a joint for a given load, or he becomes more supple for the rest of the day.

The concept of *concentric* and *eccentric* loadings

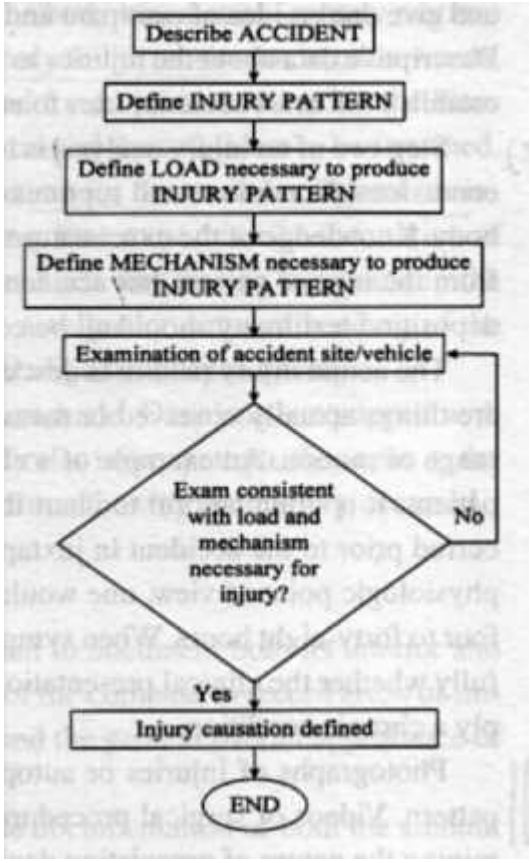


Another example appears on page 22. The author is telling us about *concentric* and *eccentric* loading. We all know about the histological structure of the muscle. Actin and Myosin filaments - also known as the thin and thick ligaments respectively - overlap to a certain degree, and when calcium ions from the sarcoplasmic reticulum arrive there, they slide over one another, causing tension - and hence contraction - in the muscle. The author tells us that the maximum load that can be generated by the sarcomere depends on how much overlap there is between the thick and thin filaments. And thus there is an optimum sarcomere length at which maximum tension can be produced. This immediately allows us to make two conclusions. If the muscle is being shortened and the sarcomeres are simultaneously activated, the muscle force drops off. This - we are told - is the *concentric* loading. On the contrary, if the muscle is being stretched at the same time when the sarcomeres are being activated, the muscle would experience an increased tension. This is known as *eccentric* loading. *The interesting thing is that straining injury typically occurs during an eccentric loading - it rarely occurs during concentric loading*. Now the author gives a concrete everyday example, which "sinks" this fact into the reader's mind. An example is given of the situation when a person steps off a bus onto the ground. The moment he does so, he experiences an increased *dynamic load*. What does this mean? The author again makes our task easier by giving yet another example. What happens when you jump on a weighing scale? The needle on the scale immediately shoots up. Thus you may be weighing just 70 kg, but if you jump over the scale, the needle may shoot up to 120 kg, or even more. So even though your static load may be 70 kg, your dynamic load during jumping is as high as 120 kg!

This is the kind of dynamic load a person experiences just after jumping off from a bus. What happens under these circumstances? Obviously the knees would tend to bend or flex, under this increased dynamic load. The thigh muscles (the quadriceps in technical language) would try to contract to overcome this bending. Now this is a typical example of eccentric loading. Quadriceps are being stretched by the dynamic load, while at the same time, they are trying to contract to keep the knee straight. And lo! You get a sprain! We all keep getting sprains off and on, and we hardly think much about them. But the way the author explains the mechanics of sprain, is simply and truly marvelous. Then the author goes on to explain why the muscle always tears off near the tendon only (he tells us that the reasons are not entirely clear to scientists currently, but one of the factors could be the short length of sarcomeres in this region).

The author is apparently inexhaustible. While describing the anatomy of the neck, he comes up with more interesting facts and analogies. The anatomy of a cervical vertebra is somewhat special. It comprises of a hard outside (cortical bone) combined with a soft inside (spongy bone). This appears to be perfect design for optimizing the compressive and torsional strengths of the vertebral body while minimizing both weight and amount of material. And what analogy can you think of this structure? Or Can you? I could not, but the author immediately breaks in to tell us that the structure is quite analogous to a *soda can filled with balsa wood*!

Flow chart for defnining injury causation

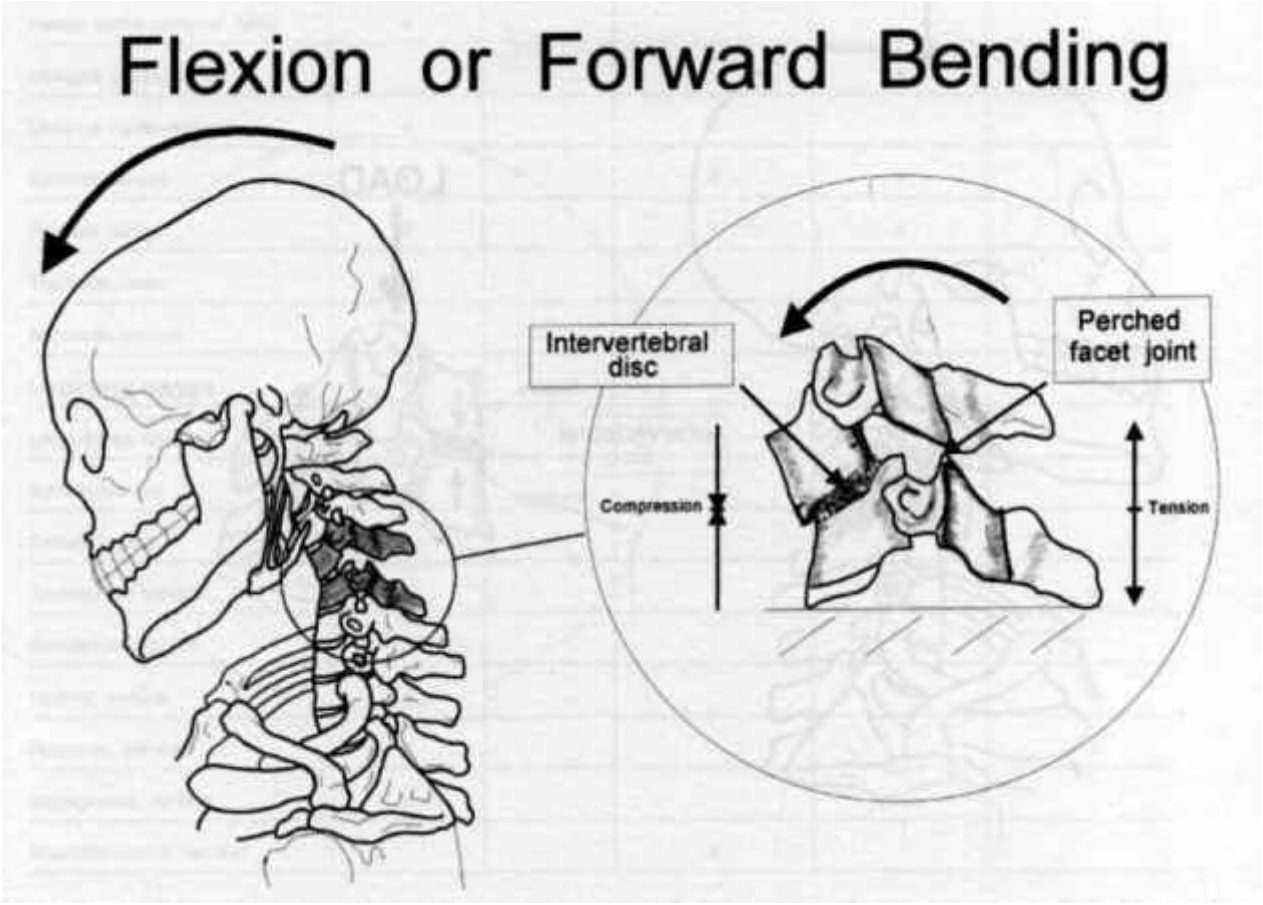


We can go on and on, and we would never end on analogies, because the author has filled up the entire book with these, which definitely makes the life of reader much simpler. But what is injury biomechanics in the first place? Well, as you might have guessed by now, it is the application of engineering principles to the understanding of how the body is injured. The author gives a very interesting and illustrative flow chart (see accompanying flow chart), by which an accurate analysis of injury causation can be determined. In the last chapter, the author gives several actual examples of how this analysis helped prove or disprove a point in a court of law. In one case, a teenage wrestler sustained a neck injury during a wrestling match, and it was contended by the parents of the wrestler that the wrestling mat was not soft enough to prevent that neck injury. A lawsuit was filed both against the manufacturer of the mat as well as against the school authorities for providing a deficient wrestling mat. On the face of it, the lawsuit appears perfectly valid, and one would tend to think the parents would have no difficulty getting an exorbitant compensation. But when we analyze the whole situation biomechanically surprising facts come to light. By making an appropriate biomechanical analysis of the whole situation, *the author not only proves that the mat was perfectly alright, but goes ahead and proves that the softer mat which the parents had been expecting from the school, would actually have caused more severe injuries in more number of*

wrestlers! Seems unbelievable at the first instance, but he does it perfectly scientifically and the way he proves this appeared to me as if he has pulled out the proverbial rabbit out of the hat like a magician! Let us see how he does this.

Step one involves description of the accident. It has already been described. The match was between a sixteen year old lad and another lad of almost the same weight (the weight of both was about 150 pounds). The "attacking" wrestler was however somewhat taller in stature. The witnesses described that at a certain point both competitors ended up facing one another in a crouched position. After that the taller wrestler dived between the legs of his opponent. The shorter wrestler fell back. The taller wrestler lifted the legs of his opponent and continued his forward movement. As a result the shorter wrestler was forced into a rearward somersault with his neck in a hyperflexed position. Just after this he felt a cracking sensation and lost the ability to use both his arms and legs.

Neck injury sustained by the young wreslter. The "jumping" or "perching" occurred at the level of C 5-6 (Click picture to enlarge)



This is simple and straightforward. Now we come to step two, which involves defining the injury pattern. The X-rays revealed bilateral "jumped" facets at the C 5-6 level of the cervical spine. After an operation, the patient became almost normal, but some neurological deficit remained.

Step three is very interesting. It involves defining the load conditions that could produce this injury. The author invokes some experimental data here and tells us that if a bending moment of *190 N-m* is applied to the neck then ligamentous damage is possible. At the time the victim was being pushed forward, his head was on the surface of the mat (the one which was supposed to be deficient in quality). This was the point of load application. Distance from this point to C5-6 (the point of injury)

is about 8 inches or 0.2 meters. This obviously becomes the moment arm, and a simple physical calculation tells us that a load of the order of 950 Newtons or 213 pounds applied to the back of the head could produce this moment. For the curious the mathematical calculation is given below.

190 N-m = 950 N x 0.2 m

No one can disagree up to this point. This is all based on hard science. No jury, no judge can deny these facts. Now comes step four, which involves defining the injury mechanism. This is straightforward. The author tell us that this load could cause tensile failure of the supraspinous ligament, the interspinous ligament, the ligamentum flavum as well as the ligaments surrounding the facet joints themselves. Step five and six are again very important steps which involve accident reconstruction and accident data consolidation. From a biomechanical standpoint, the weight of the wrestler's body on top of the bent neck of his opponent plus the dynamic load (we talked about an example earlier), caused by the sudden push provided more than enough load to cause the injury. *This level of load dwarfed the role of the wrestling mat in its ability to attenuate it*.

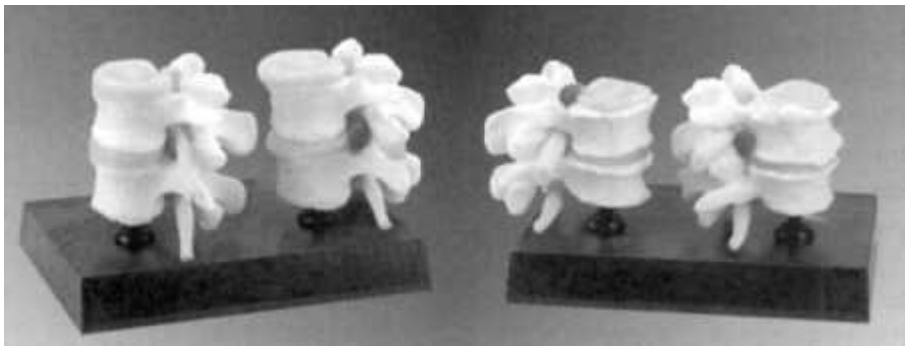
How? The mat works rather like a helmet used by bicyclists or horseback riders. The foam of the helmet absorbs the dynamic load if a person falls off a horse. However if the rider falls upside down, the total static and dynamic load can crush or bend the neck against the helmeted head which has stopped against the ground.

Some anatomical models available with *Lawyers and Judges*. Top row - from left to right: (i)Deluxe spinal column with muscles and ligaments (ii) Three lumbar vertebrae, flexibly mounted (iii) Lumbar spinal column
Bottom row: Four stage degenerative Lumbar set









The wrestling mat in question was one-and-a-quarter-inch thick. When the injured wrestler impacted his head against it, it had already "bottomed out". The other wrestler continued pressing his legs, which increased the load on his neck. Under these circumstances no mat could have prevented the injury in any way, because any mat would have "bottomed out", and once a mat is in

this condition, and further load is continually being applied, the situation becomes somewhat similar to as if the victim was being pressed against the floor itself. In fact, if the mat had been softer, it would "bottom out" under much lesser loads, causing more injuries to more people!

Sounds magical, isn't it? Well, the book is full of such examples. I would have loved to go on and on, but alas we have space limitations. And moreover no amount of summarization can do justice to the actual case studies, which tell much more than what I have just described. The author concentrates on four joints of the body - Cervical spine, lumbar spine, knee and shoulder. Injury biomechanics of several similar cases is described pertaining to each of these joints, and each case is a classic in itself.

After going through the book completely I was idly leafing through the book, and to my surprise found at the the end that *Lawyers and Judges* were even providing anatomic models of various vertebrae. I would imagine these anatomic models would go very well with this book. Interested readers may want to go through the models too. In fact in a class room set up (or for seminars or erudite lectures), one can spruce up his lectures very well by the use of these anatomical models. Several photographs are given to illustrate what the publishers are offering, but I am reproducing just four here - on the left.

Who would benefit from the book most? Obviously lawyers and accident investigators would be most interested in this book. Other people who can make good use of this book are forensic pathologist, police personnel, crime scene investigators, even engineers looking for avenues in this new and exciting branch. Fully recommended reading!

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