GLOBAL BIOMECHANICAL SOLUTIONS, INC.

11 Penn Plaza, 5th Floor
New York, NY 10001
Telephone: (212) 946-4909

INTRODUCTION

By opening this book, you have embarked on a journey into the realm of scientific application. When in law school, spending countless hours studying how words are oft times haphazardly thrown together to create reasons for certain conclusions, many students were able to take comfort that the primary skill that they were developing was the “art” of verbal distinction. This art, which has its root in creative imagination, is distinguishable from “science,” in that it lacks precision. With some circumspection, this makes perfect sense, as science comes from the root word *scire,* “to know and separate one thing from another.” Science, as it is applied, frowns on the convoluted expressions used to merely justify conclusions. Through the application of science man seeks to *know* that his conclusions are indeed true and provable, as well as ostensibly reasonable.

Science is the human effort to discover, define and understand the workings of the physical world-i.e., to know them. Of all of the disciplines of Science that man applies in his quest to know, physics is that which seeks to measure how matter and energy interact with one another. As motion and force are the products of energy, it followed that in order to understand and quantify them; motion and force would need to be isolated into a subsidiary of physics to be recognized ever after as the study of Mechanics. Consequently, as science evolved along with living things, there developed a desire to know what effect certain types of motion and force, in fact, had on living things, both as a whole, and as to the component parts of the living thing. To that end, the science of Biomechanics began its own great inquiry.

It would be error to assert that Biomechanics is a creation of man. Although man successfully identified it as a suitable subject for study, the science itself had been applied throughout pre-history. The day that the first ape chose a large enough rock, as opposed to the array of smaller, less efficient rocks, to crack open his coconut; physics was applied. As our ape became more experienced, he learned not to choose a rock that was too heavy, because he had to struggle to lift it high enough to crack the coconut; that was biomechanics. And when, supported by the weight of all of his experiences, our ape started collecting rocks that were large enough to crack the coconut, but not too heavy to lift; that was the dawn of engineering.

Biomechanical Engineering is not a new science. It has been around since the dawn of man. The beauty of physics and biomechanics is that everything in existence obeys the laws outlined in these sciences. Given like conditions in nature, these sciences can be used to identify and quantify everyday situations, every time! The laws cannot be bent, and the numbers do not lie. The purpose of this book is to introduce certain concepts of physics relative to auto collisions and the application of biomechanics to the occupants of the automobiles involved; because it is the biomechanical engineer who has extensive knowledge of mechanics with commensurate knowledge of the human body and its reaction to all motions and forces to which it may be subjected. It is imperative to understand the basic concepts of these sciences in order to understand and employ the biomechanical engineer as an expert witness in litigation.

I. WHAT IS BIOMECHANICAL ENGINEERING?

Biomechanical Engineering is the application of mechanical engineering principles to the structures of the human body. Just as a mechanical engineer evaluates how certain stress, motion and force effect a building or bridge; the biomechanical engineer studies the very bones, joints, intervertebral discs, tendons, ligaments and cartilage of the human body and the manner in which these components move and function. The biomechanical engineer seeks to measure and quantify specific types of forces and stresses to which these bodily components are subjected, and the types of forces, stresses and motions that would cause these body components to exceed their natural physiological limits.

II. WHAT IS A BIOMECHANICAL DEFENSE?

A Biomechanical Defense is a damages-based defense that is offered to challenge injury causation on the basis that a particular incident could not have caused the alleged injured body parts to exceed their natural physiological ranges of motion because the motions and forces involved were not of the type or severity to compromise the alleged injured body parts.

III. WHAT IS A BIOMECHANICAL SEATBELT DEFENSE?

A Biomechanical Seatbelt Defense is appropriate when the alleged injuries could not have been caused biomechanically if the claimant was wearing the available and operable seatbelt.

IV. *WHAT IS A BIOMECHANICAL INVESTIGATION?*

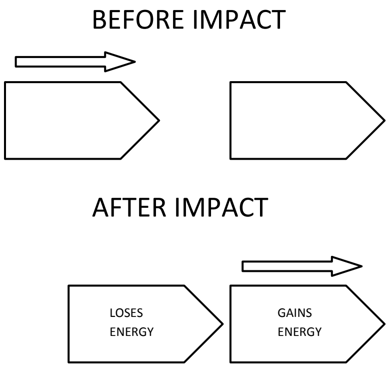
A Biomechanical Expert is an expert in forces and motions and the application of those forces and motions to the human anatomy & physiology. When a Biomechanical Expert is retained to conduct an investigation, he or she reconstructs the accident to ascertain how much force was imposed upon the vehicles and their occupants and then determines the accelerations of the vehicles and the resulting movements of the occupants. Subsequently, the expert determines whether the magnitude of force imposed upon the occupants would have compromised the alleged injured body parts and assesses whether the motions of the occupants would have caused the alleged injured body parts to exceed their natural physiological ranges of motion. Please take note that the expert's opinion must be supported by generally accepted scientific principles as evidenced by publication and peer review and the methods and processes employed by the expert in arriving at his or her conclusions must be methods and processes deemed reliable in the scientific community as evidenced by extensive testing, publication and peer review.

V. THE BASIC BIOMECHANICAL EXAMPLE

If two cars are travelling in a straight line in the same direction in the same lane of travel and the car in the rear is travelling at a higher velocity than the car in the front, at some point in time the two cars will make contact. When the two cars make contact, something magical happens in science, the faster car in the rear transfers energy to the slower car in the front, causing the slower car in the front to accelerate or speed up. However, the occupants inside the slower car in the front initially continue to travel at their pre-impact velocities as the vehicle that they are in accelerates beneath them. Since the car is now going faster than its occupants, the occupants move rearward into their seats. As a result of this, the seats load from the force of the occupants and like a spring, catapults them forward, until their seatbelts grab hold.

VI. ENERGY AND THE DELTA V (ΔV)

As you can see from the previous example, when two cars collide, energy is transferred between the vehicles. That is, one car will transfer or lose energy and the other car will receive or gain energy. When a vehicle loses energy, it will decelerate. By the same token, when a vehicle gains energy, it will, in turn, accelerate.

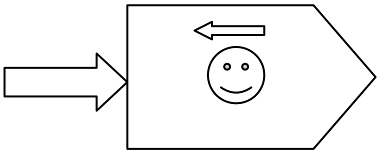


At the moment when a vehicle accelerates or decelerates, the occupants within their respective vehicles will invariably move in the direction opposite their vehicle's acceleration/deceleration. The change in velocity or delta v, expressed as ΔV, has a direct linear relationship to the energy received or lost by a vehicle during a collision. The symbol Δ stands for "change in", thus ΔV stands for "change in velocity". The ΔV is what causes the motion of the occupants inside a vehicle upon impact. This movement of the occupants inside the vehicle upon impact is what will form the basis for a claim for soft tissue injury provided that the crush or indentation that resulted to the vehicle did not intrude into the vehicle compartment itself.

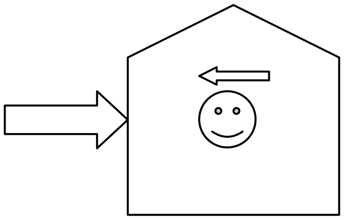
VII. ACCELERATION AND DIRECTION

First, as a general rule, vehicles accelerate or decelerate away from the point of impact, whereas their respective occupants move in a direction toward the point of impact.

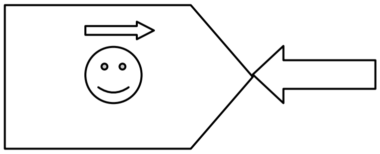
REAR IMPACT



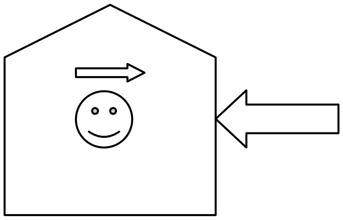
DRIVER SIDE IMPACT



FRONT IMPACT

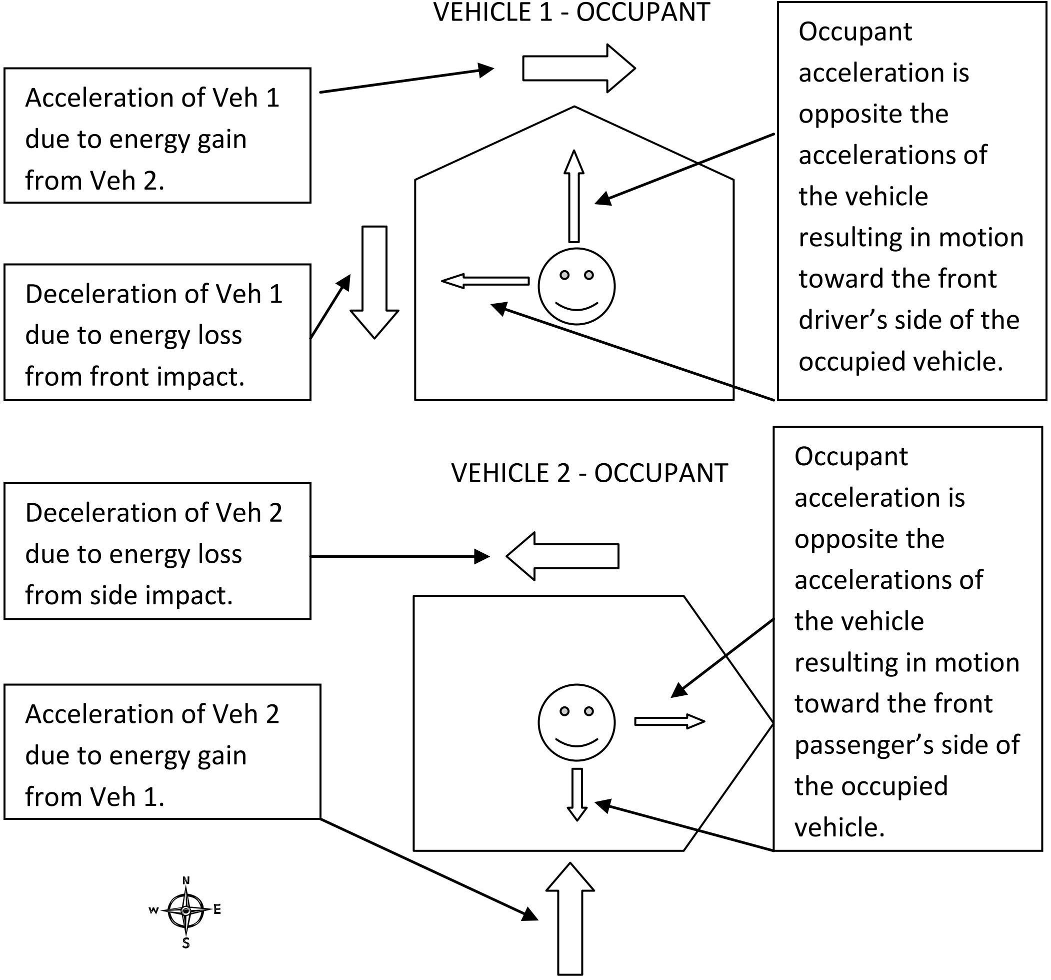


PASSENGER SIDE IMPACT



Let’s look at another example. Let’s assume that vehicle number one, which is heading north, makes contact with vehicle number two, which is travelling east. In order to analyze this accident, we need to look at the flow of energy on both the longitudinal and lateral axis.

If we are looking at vehicle number one travelling north, it will experience a deceleration longitudinally because an object is in its path. It will also experience a lateral acceleration east because of east-bound energy from vehicle number two. Moreover, vehicle number two heading east will experience a deceleration longitudinally because an object is in its path and it too will experience a lateral acceleration north because of north-bound energy from vehicle number one. The occupants inside both vehicles will move in directions opposite their respective vehicles’ acceleration/deceleration.



Acceleration of Veh 1 due to energy gain from Veh 2.

Deceleration of Veh 1 due to energy loss from front impact.

Occupant acceleration is opposite the accelerations of the vehicle resulting in motion toward the front driver’s side of the occupied vehicle.

Deceleration of Veh 2 due to energy loss from side impact.

Acceleration of Veh 2 due to energy gain from Veh 1.

Occupant acceleration is opposite the accelerations of the vehicle resulting in motion toward the front passenger’s side of the occupied vehicle.

VIII. DID CONTACT OR MOTION CAUSE THE SOFT TISSUE INJURY?

With any claim for soft tissue injuries, we can separate the injury causing mechanism into two categories: blunt impact and excessive motion. Blunt impact is simple. Let’s say that someone is walking across the street and is hit by a car, and the car made contact with the person’s femur causing a fracture. In this situation there is not any dispute over the cause of the injury. However, assume that a claimant is alleging a herniated disc in the lumbar spine from an accident in which the claimant was a belted driver of a vehicle that was hit from behind. Counsel for the defense attorney may indeed have a basis to dispute that the impact was the cause of this injury if he considers that the injury causing mechanism of the lumbar herniation will involve some form of hyper-extension or hyper-flexion. Since the claimant initially moved rearward upon impact with the seatback preventing hyper-extension, and then rebounded forward with the seatbelt restraining his forward motion, the defense attorney can show that the accident failed to involve any hyperflexion or hyper-extension; that is, the accident could not have been the cause of those injuries.

IX. FIGURING OUT THE DELTA V (ΔV)

As we have previously discussed the ΔV has to be calculated for both the longitudinal and lateral directions. As you know, a rear-end impact usually involves only a longitudinal ΔV. However, not all accidents are as simple. Many accidents involve both longitudinal and lateral accelerations. And we must, of course, keep in mind that deceleration is a negative acceleration.

Secondly, in order to figure out the ΔV for each direction – both longitudinal and lateral, we will need to figure out the following:

1) The type of impact

2) The longitudinal closing speed.

3) The masses for both vehicles involved.

4) The Coefficient of Restitution

5) The Coefficient of Friction for tires against the roadway

6) Deformation to the vehicles

The aforementioned elements must be understood before we discuss the formula for calculating the ΔV and the concept of Energy Crush Analysis. It is important for an attorney to understand the science upon which these experts base their opinions.

X. NEWTON'S LAWS

The beauty of biomechanics lies in its certainty; and it achieves that certainty through reliance on immutable natural laws-specifically, the laws of motion that were discovered by the father of physics, himself, Sir Isaac Newton.

1. Newton's First Law is that a body in motion will remain in motion in the same direction unless another body interferes with that body in motion. Moreover, a body at rest will remain at rest unless another body interferes with that body at rest.
2. Newton's Second Law is that force equals mass times acceleration:

$$F = m \times a$$

3. Newton's Third Law is that for every action, there is an equal and opposite reaction. Thus, when two bodies collide, the force sustained by both bodies will be equal in magnitude but opposite in direction.

Let's now look at how Newton's Laws relate to the ΔV.

*XI. NEWTON'S LAWS AND THE DELTA V (*ΔV)

ΔV is the change in velocity of a vehicle upon impact. Again, keeping in mind that deceleration is another way of communicating a negative acceleration; the change in velocity of a vehicle is the acceleration or deceleration that it undergoes at the moment of impact. According to Newton's Third Law, we know that when two vehicles collide, the force sustained by both vehicles is equal in magnitude but opposite in direction. Therefore the force sustained by both vehicles was the same. However, the manner in which a vehicle will react to a collision will largely be a function of its mass (Newton's Second Law states: force equals mass times acceleration or $F = m \times a$.)

So, if two vehicles collide, we know from Newton's Third Law that the force to each vehicle will be equal in magnitude but opposite in direction. So if we apply Newton's Second Law algebraically to our collision, we arrive at the following:

$$F_{v1} = m_{v1} \times a_{v1}$$

The force to vehicle #1 equals the mass of vehicle #1 times the acceleration of vehicle #1.

$$F_{v2} = m_{v2} \times a_{v2}$$

The force to vehicle #2 equals the mass of vehicle #2 times the acceleration of vehicle #2.

$$F_{v1} = F_{v2}$$

The force to vehicle #1 equals the force to vehicle #2.

$$m_{v1} \times a_{v1} = m_{v2} \times a_{v2}$$

The mass of vehicle #1 times the acceleration of vehicle #1 equals the mass of vehicle #2 times the acceleration of vehicle #2.

First, the ΔV is the acceleration component in Newton's Second Law. Remember that a negative acceleration is another way of saying deceleration. Second, we can further calculate algebraically from the above formula the following ratio:

$$\frac{a_{v1}}{a_{v2}} = \frac{m_{v2}}{m_{v1}}$$

The acceleration of vehicle #1 divided by the acceleration of vehicle #2 equals the mass of vehicle #2 divided by the mass of vehicle #1.

This ratio will make more sense when we address the method of calculating the ΔV for each directional axis. However, before we go into the principal concepts, we must lay a foundation with some elementary physics. Be patient, keep reading and understanding will be your reward.

XII. ELEMENTARY PHYSICS

In order to move forward we must understand mass, previously discussed as a component of Newton's Second Law of Motion. Mass is a measurement of a body's inertia or resistance to change and is measured in kilograms or slugs. We understand mass in a vertical sense; specifically, we view mass as weight. Weight is a measure reflecting an object's attraction to gravity, expressed mathematically; weight is equal to a body's mass times the acceleration due to gravity expressed as g.

$$W = m \times g$$

The acceleration due to gravity is the rate at which a falling object would accelerate if there was no interference from other factors like air resistance. The acceleration due to gravity is equal to:

$$g = 32.2\frac{ft}{s^2} = 9.8\frac{m}{s^2}$$

We were also discussing velocity. The average velocity of a vehicle is equal to the distance that the vehicle travels divided by the time it took to travel that distance. Hence, if a vehicle travels 50 miles and the trip takes one hour, the average velocity of the vehicle is 50 miles per hour, often seen as 50mph or 50 mi/hr. Mathematically, Average Velocity equals distance travelled divided by time:

$$v_{avg} = \frac{d}{t}$$

The term velocity often gets confused with the term speed. Velocity, however, is a vector quantity, meaning it has both magnitude and direction. Speed, by contrast, is a scalar quantity, meaning that it has magnitude only.

Acceleration was also discussed earlier in the text; and as you were previously reminded, deceleration is a negative acceleration; although the term acceleration is often used to refer to either concept. Acceleration is defined as a change in velocity. The Average Acceleration is calculated by taking the difference between Final Velocity and Initial Velocity and dividing it by time. Mathematically, this is expressed as:

$$a_{avg} = \frac{v_f - v_i}{t} = \frac{\Delta V}{t}$$

ΔV is the change in velocity upon impact. Acceleration is the change in velocity within a period of time. More specifically, ΔV is the acceleration or deceleration of a vehicle calculated in both the longitudinal and lateral directions during the time of impact. ΔV is the rate of change in velocity that the occupants of a vehicle experience inside of the vehicle upon impact.

XV. CONSERVATION OF MOMENTUM

By way of example, let us now consider the law of Conservation of Momentum. Assume that two cars are travelling in a straight line in the same direction in the same lane. Now, if the car in the rear is travelling at a higher velocity than the car in the front, at some point in time the two vehicles will make contact. We now know that when the two cars make contact, the faster car in the rear will transfer energy to the slower car in the front. More specifically, the car in the rear will lose energy and the car in the front will gain energy. The car in the rear will decelerate and the car in the front will accelerate. However, notwithstanding the transfer of energy between the two cars, the Law of Conservation of Momentum dictates that as long as an outside force does not interfere with the momentum of either of the two vehicles, the sum of the momentum of the two vehicles before the collision, will equal the sum of the momentum of the two vehicles after the collision.

Mathematically, the formula is expressed as:

$$P_{1i} + P_{2i} = P_{1f} + P_{2f}$$

The momentum of vehicle #1 before impact plus the momentum of vehicle #2 before impact equals the momentum of vehicle #1 after impact plus the momentum of vehicle #2 after impact.

Momentum is calculated as Mass times Velocity. So mathematically, we can express the above formula as follows:

$$m_1 v_{1i} + m_2 v_{2i} = m_1 v_{1f} + m_2 v_{2f}$$

All that took place in the above collision was that one car received energy and the other car transferred energy. The manner in which each vehicle reacts to the collision is governed by its mass. See Newton’s Second Law.

Conservation of Momentum must be preserved in both the longitudinal and lateral directions. For example, if we have a perpendicular type of impact in which a car heading north sustains an impact with a car heading east, both cars will be decelerated for their respective longitudinal directions of travel. Moreover, the car heading north will be accelerated east and the car heading east will be accelerated north. However, momentum will be conserved for both the northern and eastern directions of travel.

XVI. CLOSING SPEED

The Closing Speed is the net velocity of the two vehicles coming together on the same directional axis. Remember that when calculating ΔV, we need to calculate a ΔV for both the longitudinal directional axis and the lateral directional axis. So going back to our initial example of the rear-end collision, let's call the faster car in the rear the bullet and let's call the slower car in the front the target. The closing speed on the longitudinal directional axis is the pre-impact velocity of the bullet or rear-vehicle minus the pre-impact velocity of the target or front vehicle. For example, if the car in the rear is going 95 mph and the car in the front is going 90 mph, then as long as no external forces interfere, determining the ΔV for the accident is no different than if the car in the rear was going 25 mph and the car in the front was going 20 mph. More specifically, we are strictly concerned with the energy that transfers; this transfer of energy is linearly related to the ΔV. So, if the car in the rear is going 95 mph and the car in the front is going 90 mph, the closing speed is 5 mph. The two cars are coming together in the longitudinal direction at 5 mph. If the car in the rear is going 25 mph and the car in the front is going 20 mph, the closing speed in the longitudinal direction is still 5 mph.

Now we must consider perpendicular collisions, which are a bit more complicated. Again, let us learn by way of example; if a car, which is heading north, sustains a frontal impact into the passenger side doors of a car heading east, there are longitudinal and lateral ΔV's for both vehicles. However, we can only calculate a closing speed for the northbound car which will be equal to its contact speed. This is the speed at which the two vehicles closed in on each other on the north-bound axis. In a perpendicular type impact the closing speed can only be calculated for the vehicle that sustains a frontal impact. Let's now talk about contact speeds.

XVII. CALCULATING CONTACT SPEEDS

The contact speed is the vehicle's velocity immediately before impact. Let's start with an example. If a vehicle is travelling at 20 mph and then three seconds before impact, the vehicle hit's its brakes because another car is stalled in front of it, the average velocity of the vehicle during the three seconds before impact can be calculated as follows:

$$v = \frac{d}{t}$$

The "d" would be the distance travelled during the three seconds before impact. The distance is then divided by the time which is the three seconds elapsed. In common terminology when speaking about a vehicle accident, we usually communicate speed in miles/hour, time in seconds and distance in feet or meters. So, if you are given a distance in feet and time in seconds, you would do the following to get your answer in miles/hour:

Multiply by 60 squared to convert to hours,

Divide by 5280 to convert to miles

For example – if a car travelled 160 feet in ten seconds, then we can divide the 160 feet by ten seconds to come up with an average velocity of 16 feet per second and then we convert that average velocity in feet per second to feet per hour by multiplying the 16 feet per second by 60 squared to arrive at an average velocity of 57,600 feet per hour and then we can convert that average velocity in feet per hour to miles per hour by dividing 57,600 feet by 5280 to arrive at an average miles per hour velocity of 10.9 miles per hour.

However, if we can go back to the original example of the vehicle that is travelling at 20 mph and then three seconds before impact, the vehicle hit's its brakes because another car is stalled in front of it, we know that we can calculate the average velocity for the three seconds while the vehicle is hitting its brakes. But we want to know a more precise contact speed, taking into account the fact that the vehicle is decelerating as it continues to brake.

Let's take our above example and break up the three seconds before impact into three equally divided time intervals. Because of braking, the velocity of the vehicle during the first time interval is greater than the velocity of the vehicle during the second time interval and the velocity of the vehicle during the second time interval is greater than the velocity of the vehicle during the third time interval. As such, the car should be at its lowest velocity just before it contacts the other car. But, how do we figure this out?

In order to calculate the effect of braking, we need to incorporate into our calculation two concepts. The first concept is the Coefficient of Friction between the tires and the roadway; the coefficient of friction is defined by the Greek letter μ (pronounced mu). More specifically, we need to take into account the frictional force generated between the tires and the road surface. Next, we need to take into account the acceleration rate due to gravity; this is the acceleration rate at which an object would fall if no other factors like air resistance were present. Let us begin our analysis with the formula to calculate contact speed when a vehicle is decelerating due to braking.

XVIII. THE BRAKING FORMULA

The Braking Formula is expressed mathematically as follows:

$$v_i^2 - v_f^2 = 2 \times a \times d$$

The initial velocity squared minus the final velocity squared equals two times the acceleration rate times the brake distance, where the acceleration rate equals the Coefficient of Friction times the acceleration rate due to gravity.

$$a = \mu \; x \; g$$

Let's begin by talking about the Coefficient of Friction, which is basically a measure of how rough or smooth two surfaces are in relation to each other. When a car is braking, we are concerned with the Coefficient of Friction between the tires and the roadway. We are also concerned with whether the friction is starting friction or sliding friction. Starting friction is greater than sliding friction. This is why the auto manufacturers developed anti-lock brakes – to keep the car from sliding on the roadway while braking. A typical Coefficient of Friction for tires on an asphalt or tar roadway that is dry while the vehicle is travelling at less than 30 mph is between .6 and .8 or an average of .7

Let's now talk about the Acceleration Rate Due to Gravity, which is measured as 32.2 feet per second squared or 9.8 meters per second squared. As mentioned earlier, the Acceleration Due to Gravity is the rate at which a falling object would accelerate if there was no interference from other factors like air resistance.

For example, let's say that the car is travelling at 25 mph and then hit's its brakes. The car travels for a distance of 19 feet before hitting another vehicle. With a Coefficient of Friction of .7, let's calculate the contact speed.

We know that $v_i = 25mph, d = 19ft, g = 32.2\frac{ft}{s^2}, \mu = .7$

To convert 25 miles per hour to feet per second:

$$v_i = \frac{25mi}{h} \times \frac{5280ft}{mi} \times \frac{1h}{3600s} = \frac{36.67ft}{s}$$

We know that:

$$a = \mu \times g = .7 \times 32.2\frac{ft}{s^2} = 22.54\frac{ft}{s^2}$$

If we substitute into the following equation:

$v_i{}^2 - v_f{}^2 = 2 \times a \times d$

We get:

$$\left(36.67\frac{ft}{s}\right)^2 - v_f{}^2 = 2 \times 22.54\frac{ft}{s^2} \times 19ft$$

This reduces down to:

$$1344.69\frac{ft^2}{s^2} - v_f{}^2 = 856.52\frac{ft^2}{s^2}$$

And then:

$$v_f{}^2 = 488.17\frac{ft^2}{s^2}$$

When we solve for v_f, we get:

$$v_f = 22.09\frac{ft}{s}$$

To convert to miles/hr:

$$v_f = 22.09\frac{ft}{s} \times 3600\frac{s}{hr} \times \frac{1\,mile}{5280\,ft} = 15.06\ \frac{miles}{hr}$$

Hence, when the car in our example hit the other vehicle after braking for 19 feet, it was travelling at a contact speed of 15.06 mph.

XIX. COEFFICIENT OF RESTITUTION - (C_R)

The Coefficient of Restitution, denoted by C_R, is the ratio of the Separation Speed of the Vehicles to the Closing Speed. For a rear-end impact, where V_1 is the rear vehicle and V_2 is front vehicle, the formula for Coefficient of Restitution would be as follows:

$$C_R = \frac{V_{2f} - V_{1f}}{V_{1i} - V_{2i}}$$

The velocity of the front vehicle post impact minus the velocity of the rear vehicle post impact, divided by the velocity of the rear vehicle pre impact minus the velocity of the front vehicle pre impact.

XX. MATHEMATICAL FORMULA FOR DELTA V- (ΔV)

The calculation of ΔV must be performed in both the longitudinal and lateral directions. The first step is to calculate the ΔV for the longitudinal direction. Calculating the ΔV will be subject to the type of impact. If the collision involves a rear-end impact, the closing speed will be the rear vehicle's velocity minus the front vehicle's velocity and there will be no lateral component. If the collision was a perpendicular type of accident, we can calculate the closing speed for the vehicle that sustained a frontal impact, which would be that vehicle's contact speed. With that said, the ΔV of vehicle number one may be ascertained with the following equation:

$$\Delta V_1 = \frac{m_2 \times (1 + C_R) \times v}{m_1 + m_2}$$

Where m_1= mass of vehicle 1, m_2 = mass of vehicle 2, C_R = Coefficient of Restitution, v = closing speed.

The delta v of vehicle number two may be calculated as follows:

$$\Delta V_2 = \frac{m_1 \times (1 + C_R) \times v}{m_1 + m_2}$$

That's the magical formula.

XXI. ENERGY CRUSH ANALYSIS

A Biomechanical Engineer is able to calculate the amount of energy transferred or lost in a collision by analyzing the crush to a vehicle. Only one vehicle is needed to perform the analysis because the force sustained by both vehicles in a collision is the same. The force is equal in magnitude but opposite in direction for both vehicles (See Newton's Third Law). For example; if you have two identical cars built to specification in the same manner with the same materials, we can agree that if we hit one of the vehicles with a certain amount of force in a certain manner and location, the dent or deformation that will result will be almost identical to the dent or deformation that will result when we hit the other vehicle with the same amount of force in the same manner and location.

Since we may accept the aforementioned premise then we may also employ crash test studies to see how an equivalent vehicle of the same make and model were deformed under crash test scenarios when damaged in the same location. These tests serve as a point of measurement, since the data has been measured and recorded; so now we are able to determine the ΔV for the accident vehicle by comparing the deformation in the present collision against the deformation of the crash test vehicle since the deformation represents the amount of energy that the vehicle's material could not withstand. At the very least, the crash test vehicle should serve as an upper bound.

That concludes our discussion of the ΔV. Let's now move on to Biomechanics and the human anatomy and physiology.

BIOMECHANICS AND THE HUMAN ANATOMY & PHYSIOLOGY

I. ANATOMY OF THE HUMAN SPINE

The spine is made of a number of bony structures called vertebrae that stack one on top of the other. Each vertebral body has basically a hole through its center called the vertebral foramen that is essentially the pathway for the spinal cord. The spinal cord is the main conduit of the nervous system almost like a wiring harness; at different points along the spine, bundles of nerves called nerve roots branch off to the far reaches of the human body. There are cushions between each vertebra called intervertebral discs that isolate the vertebral bone structures; these are flexible structures somewhat analogous to a jelly doughnut. They essentially serve as shock absorbers for the vertebra and maintain flexibility of the spinal column. These intervertebral discs have a strong fibrous but flexible outer covering called that annulus fibrosis with an inner fluid called the nucleus pulposus which has the consistency of toothpaste. The spine consists of three major regions: cervical (C1-C7), thoracic (T1-T12) and lumbar (L1-L5), along with the sacrum and coccyx.

II. INJURY CAUSING MECHANISMS OF THE HUMAN SPINE

The most common injuries referenced in low impact auto accidents are intervertebral disc bulges and/or herniations. Damage or injury to intervertebral discs occurs when a situation creates both a mechanism for injury and enough force to exceed the strength capacity of the disc material. The mechanism for intervertebral disc herniations is hyper flexion or hyperextension and a combination of lateral bending with an application of a sudden compressive load. However, the most common disc injury is typically the result from chronic degeneration produced by repetitive loading.

III. *ANATOMY OF THE HUMAN KNEE*

The knee is an anatomically dense area where muscles, tendons, ligaments and bone come together. Generally, it is the joint where the femur (upper leg bone) and tibia (lower leg bone) come together. The primary articulation of the knee joint involves motion of the femoral condyles which are the two curved portions of the bottom portion of the femur, against the top portion of the tibia. Contact between the femur and the tibia occurs in two places: medial and lateral. The lateral and medial menisci are pieces of fibrocartilage that are attached to the top of the tibia called the tibial plateau. These crescent shaped structures of varied thickness and contour function as shock absorbers between the femur and the tibia.

The knee includes a redundant set of muscles and ligaments that control and stabilize the joint. The ligaments we will address are the ACL (anterior cruciate ligament), PCL (posterior cruciate ligament), MCL (medial collateral ligament) and LCL (lateral collateral ligament). These ligaments restrain any forward, backward or side motion of femur across the tibia.

IV. INJURY CAUSING MECHANISMS OF THE HUMAN KNEE

Injuries to the knee joint happen when an incident occurs where enough force is applied in a way that exceeds the tolerance or strength capacity of the effected tissue. The typical mechanism for meniscal injury is twisting of the knee when the knee is weight bearing and flexed. More specifically; an acute meniscus tear can only occur if the knee experiences substantial compressive loading combined with simultaneous sliding of the femur relative to the tibial plateau. An example of this mechanism may be illustrated when a football player is impacted at the knee while planting his foot to cut and change direction. Although meniscal tears can be caused by traumatic injury, injuries are very widely attributed to degeneration due to wear and tear.

Tears in the ACL and PCL can be injured in the same manner as the meniscus with a "plant and twist". The PCL can also be injured by falling on a bent knee or a strong frontal blow to the lower part of a bent leg. The ACL can also be injured by a hyperextension of the lower leg. MCL and LCL tears are most often caused by an impact to the side of the knee. Ligament tears are typically trauma related.

V. ANATOMY OF THE HUMAN SHOULDER

The shoulder is a ball-and-socket type joint, where the head of the humerus (upper arm bone) represents the ball portion of the joint and the glenoid cavity represents the socket. Since this articulation is between the humerus and the glenoid, the primary ball-and socket joint of the shoulder is also referred to as the glenohumeral joint. The glenoid labrum is a fibrocartilaginous ring that lines the glenoid cavity of the shoulder joint.

The rotator cuff tendon consists of the conjoined tendons of the four rotator cuff muscles of the shoulder: supraspinatus, infraspinatus, subscapularis, and teres minor. These tendons pass under the coracoacromial arch, consisting of the acromion, acromioclavicular joint, coracoacromialligament, and coracoid, and fuse to form a cuff surrounding the humeral head before they insert into the humerus.

VI. INJURY CAUSING MECHANISMS OF THE SHOULDER

Due to the design of the shoulder, all movements of the shoulder, especially overhead movements, compress the rotator cuff tendon repeatedly against the coracoacromial arch. The repeated compression over time may result in degenerative pathology defined as a rotator cuff tear. Many will attribute the onset of symptoms to a specific traumatic event, but a rotator cuff tear is of chronic origin related to multiple factors such as overuse and aging. The rotator cuff is commonly injured during repetitive use of the upper limb above the horizontal plane in activities such as throwing, racket sports and swimming.

Impingement syndrome is the term used for the irritation of the tendons and bursa from repeated contact with the undersurface of the acromion. This also is associated with repetitive trauma caused by occupational or athletic endeavors and/or degenerative bony growth projecting outward from the surface of the bone.

Injuries to the glenoid labrum can occur during a sudden impact that forces the head of the humerus into the glenoid cavity. For example: falling on an outstretched arm.

ABOUT THE AUTHORS:

Sean M. Connors, J.D., Sales Director*- a former attorney practicing in Insurance Defense; a graduate of Saint John's University school of Law and Fordham University; a co-author of the "Biomechanical Manual for Automobile Litigation" and featured writer for Insurance Defense Magazine.*

Sean O'Loughlin, Esq., President *- a graduate of Brooklyn Law School and Baruch College; an attorney and an accountant; was directly responsible for creating & developing American Transit Insurance Company's Special Operations Department and Biomechanical Program and he was part of a team of professionals innovating the use of biomechanical experts in automobile litigation in the great State of New York.*

John T. Montalbano, Vice President & Chief Operating Officer *- an Engineer with over 15 years of engineering experience, including biomechanics, neuroscience, medical devices & ultrasound; a former managing engineer in American Transit Insurance Company's Biomechanical Program; a graduate of Polytechnic University; a co-author of the "Biomechanical Manual for Automobile Litigation" and was a featured speaker for the New York State Bar Association's seminar titled "Establishing the Biomechanical Defense."*