



## **Course instructions:**

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## **Chiropractic Treatment of Auto Accident Injuries**

### **Motor Vehicle Accident Statistics**

- Motor vehicle accidents account for more deaths than all natural disasters combined. In the United States the probability of being injured in a motor vehicle accident is greater than one in one thousand in any one year.
- A male is twice as likely to die in a motor vehicle accident as a female.
- The ages of 16 and 24 are the most dangerous for both sexes.
- Between the ages of 16 and 64 alcohol intoxication is responsible for over 20% of all fatal accidents, and between the ages of 21 and 44 almost 50% of all fatalities.
- Between the ages of 16 and 44 the fatality rate has declined since 1975. The most significant decline being in the 16 - 20 year old age group.
- About half of all motor vehicle accidents result in injuries or fatalities.
- Over two thirds of all of the people who die in vehicles are not wearing safety restraints properly.
- You are ten times more likely to die driving a motor cycle than if you are driving any other motor vehicle.<sup>1</sup>

### **Take Care When You Take a Walk**

The National Highway Traffic Safety Administration (NHTSA) says pedestrians are 36 times more likely to die in traffic (per miles traveled) than drivers. A National Highway Traffic Safety Administration study found that 12 percent of the 42,116 traffic deaths in 2001 involved pedestrians. Out of those deaths:

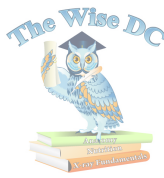
- More than half involved three groups; children under age 16 (10 percent), people 65 and older (21 percent) and people impaired by alcohol (32 percent).
- Most took place in urban areas (69 percent) and spots where crosswalks were lacking or ignored (79 percent).
- Most took place at night (64 percent).<sup>2</sup>

### **Traffic Accident Defined**

A traffic accident is defined as any vehicle accident occurring on a public highway (originating on, terminating on, or involving a vehicle partially on the highway). These accidents therefore include collisions between vehicles and animals, vehicles and pedestrians, vehicles and fixed obstacles and single vehicle accidents.<sup>3</sup>

### **The Global Motor Vehicle Accident Apocalypse**

At present, road traffic accidents rank among the top ten leading causes of disease as measured in DALYs (disability-adjusted life years). According to a World Health Organization/World



Bank report "The Global Burden of Disease", deaths from non-communicable diseases are expected to climb from 28.1 million a year in 1990 to 49.7 million by 2020 - an increase in absolute numbers of 77%. Traffic accidents are the main cause of this rise. Road traffic injuries are expected to take third place in the ranking order of disease burdens by the year 2020, ahead of fatalities caused by war and violence.<sup>4</sup>

The 1999 World Health Organization publication "Injury: A Leading Cause of the Global Burden of Disease," reports that the leading injury-related cause of death among people aged 15-44 years is traffic injuries. Of the 5.8 million people who died of injuries in 1998, 1,170,694 died as a direct result of injuries sustained in a motor vehicle accident. The World Health Organization reports that 38,848,625 injuries were received by people involved in motor vehicle accidents in 1998.<sup>5</sup>

### **United States Transportation Fatality and Injury Statistics**

In the United States the death toll on highways makes driving the number one cause of death and injury for young people ages 5 to 27. Highway crashes cause 94 percent of all transportation fatalities and 99 percent of all transportation injuries. However, traffic safety programs receive only one percent of the funding of the United States Department of Transportation's annual budget.<sup>6</sup>

### **The Injury Pyramid**

According to a World Health Organization report, "The Injury Pyramid," for every motor vehicle injury resulting in death in the United States, 13 people sustain injuries severe enough to require hospitalization.<sup>7</sup>

### **United States Department of Transportation Findings**

In the United States Department of Transportation publication "The Economic Costs Of Motor Vehicle Crashes," National Highway Traffic Safety Administration investigator Lawrence J. Blincoe reports that in 1994 motor vehicle crashes accounted for 40,676 fatalities, and 4,100,000 injuries (of which 533,000 or 13% were serious). The total lifetime cost to the US economy for automobile accidents that occurred in 1994 was \$150.5 billion.<sup>8</sup>

### **National Highway Traffic Safety Administration Statistics**

In 1998 the National Highway Traffic Safety Administration reported 3,192,000 injuries, 414,960 of them serious and 41,471 fatalities from vehicle accidents.<sup>9</sup>

### **Advocates for Highway and Auto Safety Truck and SUV Crash Statistics**

Each year nearly 5,000 Americans die in truck crashes. In 1995, 98 percent of the people killed in two-vehicle crashes involving passenger cars and big trucks were occupants of the passenger vehicles. Since 1992, there have been more fatalities in collisions involving SUVs and cars than in car-to-car crashes, largely as a result of the disparity in vehicle weight (mass), height, and front-end configuration between SUVs and passenger cars. Of those persons fatally injured in SUV and car collisions, eighty percent were car occupants.<sup>10</sup>

## Bureau of Transportation Statistics Transportation Fatalities by Mode

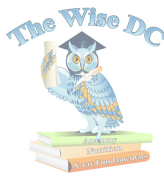
	2000	2001	2002
<b>TOTAL fatalities</b>	<b>44,333</b>	<b>44,933</b>	Unknown
<b>Air</b>	<b>763</b>	<b>1770</b>	<b>609</b>
U.S. air carrier	92	531	0
Commuter carrier	5	13	0
On-demand air taxi	71	60	33
General aviation	595	562	576
<b>Highway, total</b>	<b>41,945</b>	<b>42,196</b>	<b>42,815</b>
Passenger car occupants	20,699	20,320	20,416
Motorcyclists	2,897	3,197	3,244
Truck occupants, light	11,526	11,723	12,182
Truck occupants, large	754	708	684
Bus occupants	22	34	45
Pedestrians	4,763	4,901	4,808
Pedalcyclists	693	732	662
Other	591	581	774
<b>Railroad</b>	<b>937</b>	<b>971</b>	<b>951</b>
<b>Waterborne, total</b>	<b>838</b>	<b>820</b>	Unknown
Vessel-related	49	59	28
Not related to vessel casualties	88	80	48
Recreational boating	701	681	Unknown

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### Cervical Whiplash Defined

The term “whiplash”, coined in 1928 by Crowe, describes a particular mechanism of injury to the head and neck. During sudden acceleration or deceleration, as happens commonly in an auto accident, the inertia of the head may cause it to be thrown forwards, backwards, or sideways, and then to rebound in the opposite direction. This alternating motion is called whiplash. Whiplash is analogous to the forward and backward motion of the tip of a whip when it is cracked.” “Whiplash” is a pattern of movement and not an injury in itself.<sup>12</sup>

Each year over one million people in the United States sustain whiplash injuries. About 25 percent result in long term chronic disorders although some literature suggests that 43 percent of patients will suffer long-term symptoms. One study reported that after six months, 38 percent of patients still reported daily or constant symptoms. Common symptoms of whiplash include headache; neck pain and stiffness; nausea; pain; weakness and paresthesia of the arms; thoracic and lumbar spinal pain; insomnia; dizziness; memory loss; visual disturbances; and psychiatric disorders such as depression and anxiety.<sup>13</sup>



## **Cervical Whiplash Injury Mechanism**

Any accident involving sudden acceleration or deceleration can cause a whiplash injury if the victim's head is unrestrained and free to move relative to the torso. Headrests do not prevent whiplash injuries, though they may reduce their severity. Seatbelts, though they reduce the risk of fatal injuries, may actually increase the severity of whiplash injuries by locking the torso in place so there is more shearing force between it and the head when the vehicle is jolted. As for chronicity, the duration of symptoms bears no relation to the amount of damage to the automobile (based on repair costs), nor even to whether the occupant's seat was damaged or torn from its tracks.<sup>14</sup>

The acceleration-deceleration forces which cause whiplash injury are sufficient to permanently disable an individual. Even in a low speed rear impact collision of 8 mph, the head moves roughly 18 inches, at a force as great as 7 G's in less than a quarter of a second. To put this into perspective, the Discovery space shuttle is only built to withstand a maximum of 3 G's.<sup>15</sup>

Whiplash is the unequal transfer of energy to the neck. The force that an accident victim is exposed to is generally two and a half times greater than that which the vehicle is struck. A common misconception is that if there is no vehicle damage, there would be equally little or no injury. Manufacturers use of rigid or stiff motor vehicle bodies and chassis as well as improved bumper systems also produce an increased G force to occupants involved in car accidents.<sup>16</sup>

Early whiplash tests utilized monkeys and cadavers to understand the mechanics of the injury. Accident reconstruction experts measure the injurious forces generated in a car accident with arrays of accelerometers attached to a crash test volunteer. Occupant G forces are compared to vehicle velocity and the change in velocity of the impact vehicle. The G force calculation of the change in velocity of the impact vehicle is called Delta V.<sup>17</sup>

Recent studies at Chalmers University of Technology in Sweden suggest that rapid changes in the spinal column pressure cause damage to the nerves. Rapid change in the spinal fluid result in pressure damage to nerve fibers because the forces that occur during a rear impact happen too fast to allow normal fluid exchange. This research indicates that the speed at which the motion occurs is more critical compared to the extent of the neck motion. Some studies show that the range of motion is equally important.<sup>18</sup>

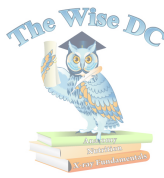
Head angular acceleration and resultant linear head acceleration are considered key injury predictors. The head angular acceleration refers to the speed of the rotation of the head around its axis and the resultant linear head acceleration refers to the overall speed the head travels on a linear or horizontal plane. Reducing either or both of these factors would result in reducing the severity and duration of whiplash injuries.<sup>19</sup>

## **Whiplash Studies**

“When vehicle occupants involved in rear crashes had their heads against the head restraint during impact no injury occurred.” (Jakobsson,L.; Svensson,M.Y. 1994 Volvo Car Corp.)

“44 mph impacts can be sustained without injury if no relative motion occurs between the head and torso.” (Mertz, H. and Patrick, L. 1967 Car crash conference CA, USA.)

“Predictors of whiplash identified were neck shear force, neck tensile force and head angular



acceleration”. (Jakobsson,L.; Svensson,M.Y. 1994 Volvo Car Corp.)

“A significant increase in injury duration occurred when the occupant's head was more than 4 inches away from the head restraint.” (Olsson, I. 1990 International Conference on Biomechanics of Impacts, Bron-Lyon, France)<sup>20</sup>

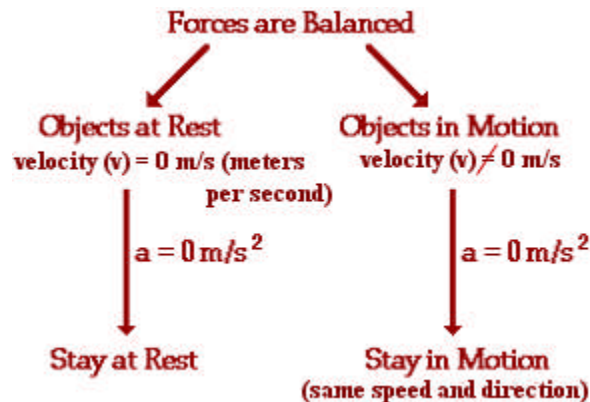
## The Fundamentals of Physics

### Newton's Laws of Motion

Isaac Newton (a 17th century scientist) put forth three laws which explain why objects move or remain stationary. These three laws have become known as Newton's three laws of motion.

#### Newton's First Law of Motion

Newton's first law of motion is often referred to as the "law of inertia." Newton's first law states that an object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.



If an object is in motion with an eastward velocity of 5 meters per second, it will continue in this same state of motion (5 m/s, East). If in motion with a leftward velocity of 2 m/s, it will continue in this same state of motion (2 m/s, left). The state of motion of an object is maintained as long as the object is not acted upon by an unbalanced force. All objects resist changes in their state of motion.

Inertia (resisting changes in the state of motion) occurs in an automobile while it is braking to a stop. The force of the road on the locked wheels provides the unbalanced force to change the car's state of motion, however there is no unbalanced force to change the passenger's own state of motion. Therefore, the passenger continues in motion, sliding forward along their seat. A person in motion tends to stay in motion with the same speed and in the same direction ... unless acted upon by the unbalanced force of a seat belt. The seat belt provides the unbalanced force which brings the occupant of a vehicle from a state of motion to a state of rest.

Other examples of Newton's first law of motion.

- Blood rushes from your head to your feet when riding on a descending elevator which suddenly stops.
- To dislodge ketchup from the bottom of a ketchup bottle, the bottle is often turned upside down, thrust downward at a high speed and then abruptly halted.

The law of inertia states that if the forces acting upon an object are balanced, then the acceleration of that object will be  $0 \text{ m/s}^2$ . Objects at equilibrium will not accelerate. An unbalanced force acting upon an object will accelerate it by changing its speed, direction or both.

The law of inertia is commonly experienced when riding in cars and trucks. The tendency of moving objects to continue in motion is a common cause of a variety of transportation accidents. Consider for example a ladder strapped to the top of a truck. As the truck travels down the road, the ladder moves with it. Since the ladder is strapped tightly to the truck, the ladder shares the same state of motion as the truck. As the truck accelerates, the ladder accelerates with it. If the truck were to abruptly stop and the straps were no longer functioning, then the ladder in motion would continue in motion.



## The Meaning of Force

A force is a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force acting on each of the objects. When the interaction ceases, the two objects no longer experience a force. Forces only exist as a result of an interaction.

All forces (interactions) between objects can be placed into two broad categories:

- contact forces, and
- forces resulting from action-at-a-distance

**Contact forces** are types of forces in which the two interacting objects are physically in contact with each other. Examples of contact forces include frictional forces, and tensional forces.

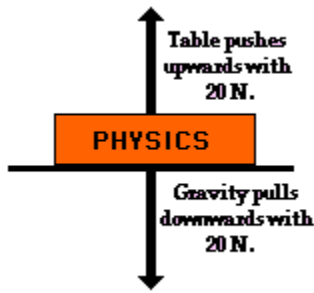
**Action-at-a-distance forces** are types of forces in which the two interacting objects are not in physical contact with each other, but are able to exert a push or pull despite the physical separation. Examples of action-at-a-distance forces include gravitational forces (e.g., the sun and planets exert a gravitational pull on each other despite their large spatial separation).

Force is a quantity which is measured using a standard metric unit known as the Newton. One Newton is the amount of force required to give a 1-kg mass an acceleration of  $1 \text{ m/s}^2$ . A Newton is abbreviated by an "N."

$$1 \text{ Newton} = 1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$$

Force is a vector quantity. A vector quantity is a quantity which has both magnitude and direction. To describe the force acting upon an object, you must describe both its magnitude (size) and its direction. Thus, 10 Newtons is not a full description of the force acting upon an object. In contrast, 10 Newtons, downwards is a complete description of the force acting upon an object; both the magnitude (10 Newtons) and the direction (downwards) are given.





Since forces are vectors, the influence of one individual force upon an object is often canceled by the influence of another force acting on the same object. For example, the influence of a 20-Newton upward force acting upon a book is canceled by the influence of a 20-Newton downward force acting upon the book. In such instances, the two individual forces are said to "balance each other".

## Gravitational Force

<p>Gravity Force (also known as Weight) <math>F_{\text{grav}}</math></p>	<p>The force of gravity is the force with which the earth, moon, or other massive body attracts an object towards itself. By definition, this is the weight of the object. All objects upon earth experience a force of gravity which is directed "downward" towards the center of the earth. The force of gravity on an object on earth is always equal to the weight of the object as given by the equation:</p> $F_{\text{grav}} = m \times g$ <p>where:  <math>g</math> = acceleration of gravity = <math>9.8 \text{ m/s}^2</math> (on Earth)  <math>m</math> = mass (in kg)</p>
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## Mass vs. Weight

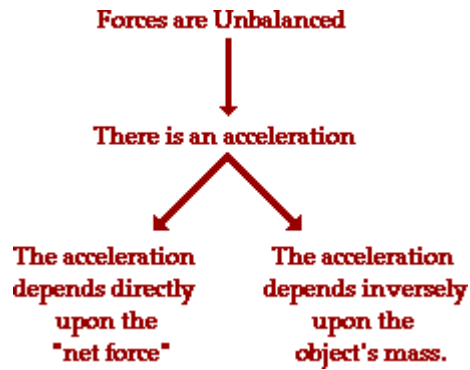
The mass of an object refers to the amount of matter that is contained by the object; the weight of an object is the force of gravity acting upon that object.

The mass of an object (measured in kg) will be the same no matter where in the universe that object is located. Mass is never altered by location, the pull of gravity, speed or even the existence of other forces. For example, a 2-kg object will have a mass of 2 kg whether it is located on Earth, or the moon.

The weight of an object (measured in Newtons) will vary according to where in the universe the object is. Weight depends upon which planet is exerting the force and the distance the object is from the planet. Weight, being equivalent to the force of gravity, is dependent upon the value of  $g$  (acceleration of gravity). On Earth's surface,  $g$  is  $9.8 \text{ m/s}^2$  (often approximated to  $10 \text{ m/s}^2$ ). On the moon's surface,  $g$  is  $1.7 \text{ m/s}^2$ . The  $g$  value is inversely proportional to the distance from the center of the planet. So if  $g$  were measured at a distance of 400 kilometers above the earth's surface, you would find the value of  $g$  to be less than  $9.8 \text{ m/s}^2$ .

## Newton's Second Law

Newton's second law of motion pertains to the behavior of objects when all existing forces are not balanced. The second law states that the acceleration of an object is dependent upon two variables – the net force acting upon the object and the mass of the object. The acceleration of an object depends directly upon the net force acting upon the object, and inversely upon the mass of the object. As the net force increases, so will the object's acceleration. However, as the mass of the object increases, its acceleration will decrease.



The equation for Newton's second law of motion:  $F_{\text{net}} = m \times a$  (Net force = mass times acceleration). The net force is equal to the product of the object's mass and its acceleration.

Acceleration is produced by a "net force." The net force is the vector sum of all the forces. If all the individual forces acting upon an object are known, then the net force can be determined. The above equation also indicates that a unit of force is equal to a unit of mass multiplied by a unit of acceleration. By substituting standard metric units for force, mass, and acceleration into the above equation, the following unit equivalency can be written:

$$1 \text{ Newton} = 1 \text{ kg} \cdot \frac{\text{m}}{\text{s}^2}$$

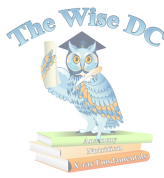
One Newton is defined as the amount of force required to give a 1-kg mass an acceleration of  $1 \text{ m/s}^2$ . To summarize Newton's first and second laws, an object will accelerate if the forces acting upon it are unbalanced and the amount of acceleration is directly proportional to the amount of net force acting upon it.

### Newton's Third Law

A force is a push or a pull upon an object which results from its interaction with another object. According to Newton, whenever objects A and B interact with each other, they exert forces upon each other. When you sit in your chair, your body exerts a downward force on the chair and the chair exerts an upward force on your body. There are two forces resulting from this interaction — a force on the chair and a force on your body. These two forces are called action and reaction forces.

Newton's third law states that for every action, there is an equal and opposite reaction. The statement means that in every interaction, there is a pair of forces acting on the two interacting objects. The size of the force on the first object equals the size of the force on the second object. The direction of the force on the first object is opposite to the direction of the force on the second object. Forces always come in pairs – equal and opposite action-reaction force pairs. An example of this would be force generated by the wheels of a car. An automobile is equipped with wheels that spin backwards. As the wheels spin backwards, they push the road backwards. In turn, the road reacts by pushing the wheels forward. The size of the force on the road equals the size of the force on the wheels (or automobile); the direction of the force on the road (backwards) is opposite to the direction of the force on the wheels (forwards). For every action, there is an equal (in size) and opposite (in direction) reaction. Action-reaction force pairs make it possible for automobiles to move.<sup>21</sup>





## Physics Definitions

### g Force

**g** (also *g-force* or *g-load*) is a unit of acceleration. Acceleration is defined as the rate of change of velocity. It is thus a vector quantity with dimension length / time<sup>2</sup>. To accelerate an object is to change its velocity over a period of time. **g** force is defined as exactly 9.80665 m/s<sup>2</sup>, approximately equal to the acceleration due to gravity on the earth. Gravitation is the force of attraction that exists between all particles with mass in the universe. <sup>22</sup>

## Vehicle Crash Testing

All crash tests in the United States are conducted using the Hybrid III crash dummy. This guarantees consistent results. A dummy is built from materials that mimic the physiology of the human body. For example, the crash dummy has a spine made from alternating layers of metal discs and rubber pads.

### Crash Dummy Morphology

The dummies come in different sizes and they are referred to by percentile and gender. For example, the 50th-percentile male dummy represents the median sized male. This is the dummy most commonly used in crash testing. It weighs 172 lbs and is 5 ft 9 inches tall.

The dummies contain three types of instrumentation:

- Accelerometers
- Load Sensors
- Motion Sensors

### Accelerometers

These devices measure the acceleration in a particular direction. This data can be used to determine the probability of injury. Acceleration is the rate at which speed changes. For example, if you bang your head into a brick wall, the speed of your head changes very quickly. Conversely, if you bang your head into a pillow, the speed of your head changes more slowly as the pillow cushions the force.

The crash-test dummy has accelerometers throughout its body. Inside the dummy's head, there is an accelerometer that measures the acceleration in all three directions (front-back, up-down, left-right). There are also accelerometers in the chest, pelvis, legs, feet and other parts of the body.

### Load Sensors

Inside the dummy are load sensors that measure the amount of force on different body parts during a crash. The maximum load in the bone can be used to determine the probability of it breaking.

### Movement Sensors

These sensors are used in the dummy's chest. They measure how much the chest deflects during a crash.

### An Actual Crash Test

The National Highway Traffic Safety Administration (NHTSA) conducts two types of crash tests



as part of the New Car Assessment Program.

- 35 mph frontal impact: The car runs straight into a solid concrete barrier. This is equivalent to a car moving at 70 mph hitting a stationary car of the same weight.
- 35 mph side impact: A 3015-pound sled with a deformable "bumper" runs into the side of the test vehicle. The sled's tires are angled. The test simulates a car that is crossing an intersection being sideswiped by a car running a red light. The sled actually moves at 38.5 mph, but when you do the math, it is equivalent to a 35 mph side impact because of the way the wheels on the sled are angled.

## **Crash Test Paint**

Before the crash-test dummies are placed in the vehicle, researchers apply paint to them. Different colors of paint are applied to the parts of the dummies' bodies most likely to hit during a crash. The dummy's knees, face and areas of the skull are each painted with a different color. If researchers note a particularly large acceleration in the data from the accelerometers in the dummy driver's head, the paint marks in the car will indicate what part of the body hit what part of the vehicle inside the cabin. This information helps researchers develop improvements to prevent that type of injury in future crashes.

There are 15 high-speed cameras, including several under the car pointed upward. They shoot around 1,000 frames per second. Next, the car is backed away from the barrier and prepared to crash. A pulley, mounted in a track, pulls the car down the runway. The car hits the barrier at 35 mph. It only takes about 0.1 seconds from the time the car hits the barrier until it stops.

## **Surviving A Crash**

Safety systems in your car minimize the risk of injury by dissipating kinetic energy slowly and evenly.

All new cars have seatbelt pretensioners and force limiters. These devices tighten up the seatbelts very soon after your car hits a barrier, but before the airbags deploy. The seatbelt can then absorb some of your energy as you move forward towards the airbag. Milliseconds later, the force in the seatbelt holding you back would cause injury, therefore, the force limiters engage, thereby making sure the force in the seatbelts doesn't get too high. Next, the airbag deploys and absorbs some more of your forward motion while protecting you from hitting the dashboard, steering wheel, or windshield.

## **National Highway Traffic Safety Administration Rating System**

Researchers have used crash test data to determine the likelihood of injuries that may be sustained in a crash. This data was used to create the National Highway Traffic Safety Administration's star system. This system makes automobile safety ratings easier for consumers to understand when buying a car. In frontal crashes, the star rating is determined by the worst score on these three criteria:

- Head Injury Criteria (HIC) , Chest deceleration, and Femur load.

In order to receive a five star rating, all three of these criteria must be below the level that indicates a 10 percent chance of severe injury.

<b>Ratings for Frontal-Impact Tests</b>	
<b># of Stars</b>	<b>Result</b>
5 Stars	10 percent or less chance of serious injury
4 Stars	11 to 20 percent chance of serious injury
3 Stars	21 to 35 percent chance of serious injury
2 Stars	36 to 45 percent chance of serious injury
1 Star	46 percent or greater chance of serious injury

In side-impact crashes, there are two criteria:

- Thoracic Trauma Index (TTI), and Lateral Pelvic Acceleration (LPA).
- To achieve a five star rating in side-impact crashes, both criteria must be in the range that indicates less than a 5 percent chance of serious injury.

<b>Ratings for Side-Impact Tests</b>	
<b># of Stars</b>	<b>Result</b>
5 Stars	5 percent or less chance of serious injury
4 Stars	6 to 10 percent chance of serious injury
3 Stars	11 to 20 percent chance of serious injury
2 Stars	21 to 25 percent chance of serious injury
1 Star	26 percent or greater chance of serious injury

## Whiplash Dynamics

175 milliseconds

- Head is still moving backwards
- Car seat begins to spring forward
- Torso is again accelerated forward



### Motion During a Collision

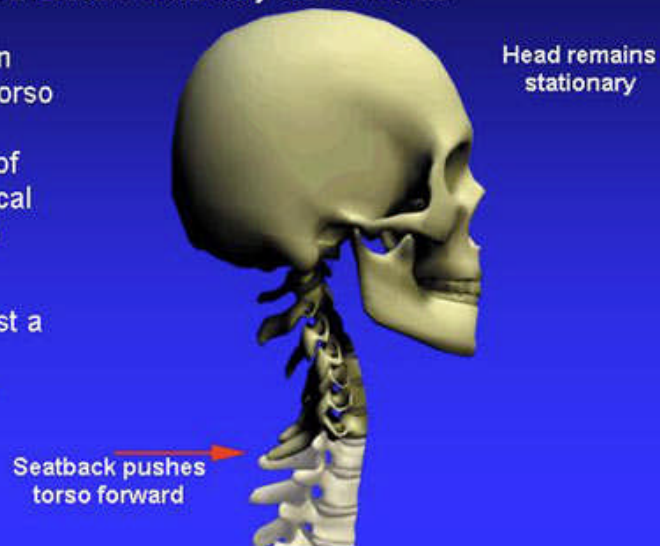
75 milliseconds

At this point in the collision, the car seat is rapidly pushing the occupant's torso forward, while the head remains stationary due to inertia.



This difference in motion between the neck and torso results in an S-shaped curve, where nearly all of the bending in the cervical spine takes place in the lower cervical spine.

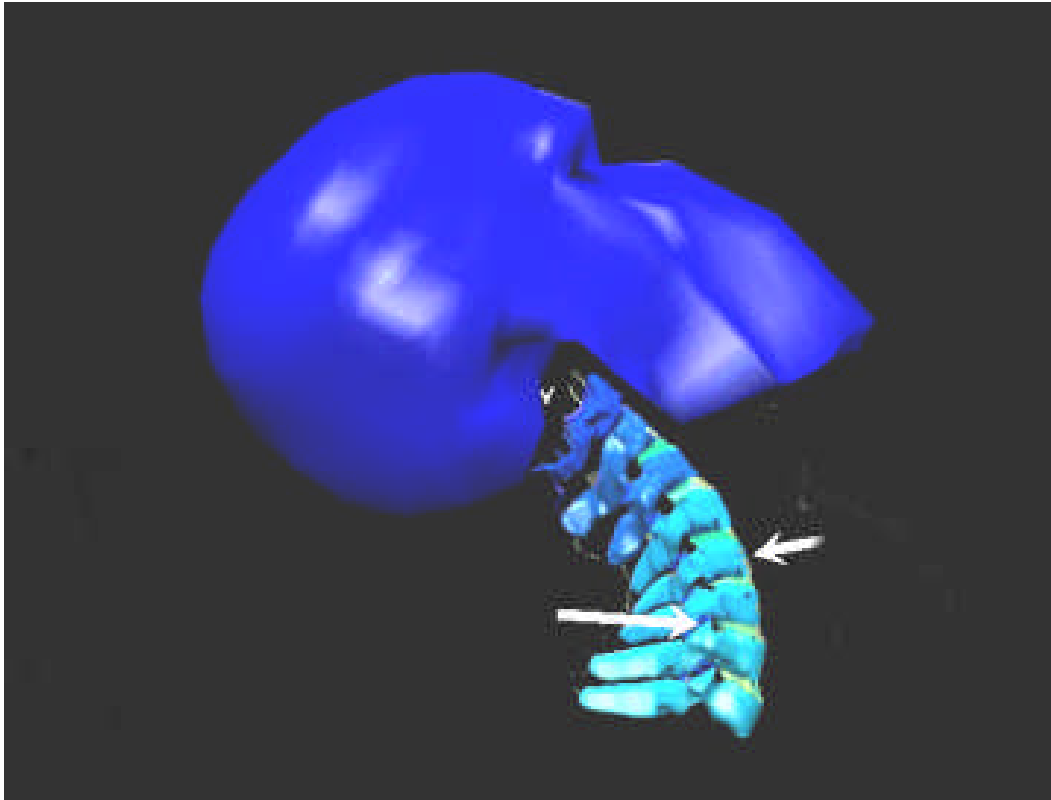
This rapid bending in just a few joints can result in ligament damage in the lower spine.



## Whiplash Pathophysiology

The whiplash mechanism can cause derangements of structures, such as ligaments, nerves, vertebrae and blood vessels, as well as disorders of function, such as poor posture and decreased ranges of motion.

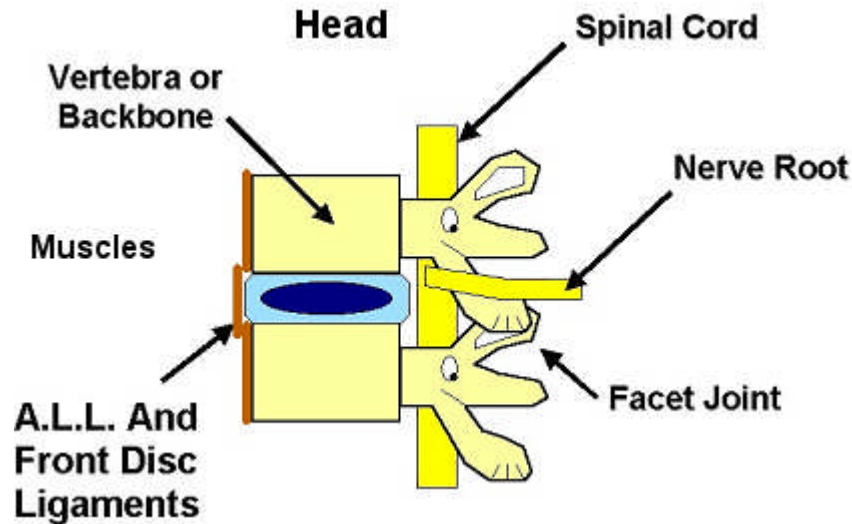
### Whiplash Produces An S-shaped Curvature of the Neck with Hyperextension at Lower Levels



In a rear end collision the head travels backward, and either hits against a good headrest, or if the headrest is too low or not there, it travels backward until the facet joints in the back of the spine and/or the ligaments in the front of the neck stop it. The most commonly injured muscles are the sternocleidomastoids and longus colli. The most commonly injured ligament is the anterior longitudinal ligament. The most recent research suggests that rather than coming straight back, the neck actually takes on an s-shaped curve in a rear end accident. When an injury occurs traction is an effective treatment methodology to heal these injured joints.<sup>24</sup>

**RESULTS:** In the whiplash traumas, the peak intervertebral rotations of C6-C7 and C7-T1 significantly exceeded the maximum physiologic extension for all trauma cases studied. The maximum extension of these lower levels occurred significantly before full neck extension. In fact, the upper cervical levels were consistently in flexion at the time of maximum lower level extension. **CONCLUSIONS:** In whiplash, the neck forms an S-shaped curvature, with lower level hyperextension and upper level flexion. This was identified as the injury stage for the lower cervical levels. A subsequent C-shaped curvature with extension of the entire cervical spine produced less lower level extension.<sup>25</sup>

## Commonly Injured Structures Due to Whiplash Injury



### I. Cervical Spine Anatomy and Neurology

#### Spinal Anatomy Overview

- The spinal column is composed of the 24 moveable vertebrae, sacrum and coccyx.
- The average adult male spinal column measures 71 cm (28").
- The average adult female spinal column is about 61 cm (25").<sup>26</sup>

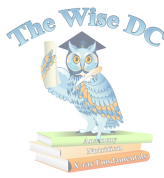
#### The Spinal Canal

- The spinal canal houses the medulla spinalis (spinal cord). The spinal canal begins at the foramen magnum and ends at the apex of the sacrum.
- The spinal canal's boundaries are the posterior portion of the vertebral bodies at the anterior and the vertebral arches at the posterior and lateral aspects.
- Cervical: The spinal canal is largest in the cervical region. The shape of the canal is triangular. The transverse diameter is greater than the anteroposterior diameter.
- Thoracic: The spinal canal is smallest in the thoracic region and is circular in shape.
- Lumbar: The canal in the lumbar region becomes larger due to the diffusion of the spinal nerve roots to form the cauda equina. The shape of the canal is triangular, making it similar to the cervical region.
- Sacral: The spinal canal in the sacral region remains triangular in shape and ends at the sacral hiatus at the sacral apex.<sup>27</sup>

#### Intervertebral Foramina

- The intervertebral foramina (IVF's) are ovoid holes formed when the superior vertebral notch of one vertebra meets the inferior vertebral notch of the vertebra above. There are 31 pairs of IVF's. The primary structures found in an IVF are the spinal nerve and spinal vessels (artery and veins).
- The IVF's are smallest in the cervical region and largest in the lumbar region. The foramina change in size with spinal movements. Flexion in the cervical and lumbar spine increases the size of the IVF's, whereas extension in these areas decreases the foramina's size.



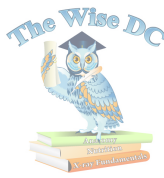


## Intervertebral Disks

- The intervertebral disks (IVD's) are classified as ligaments of the vertebral column.
- There are 23 intervertebral disks in the human vertebral column. The first being between the vertebral bodies of axis and the third cervical vertebra. The last IVD is between the fifth lumbar and sacral base.
- IVD's are largest and thickest in the lumbar region and smallest and thinnest in the cervical spine. In the cervical and lumbar regions the IVD's are also thicker at the anterior due to the secondary lordotic curve in these areas. The anterior-posterior thickness of the disks in the thoracic spine is equal.
- The disks are adherent to thin layers of hyaline cartilage which cover the superior and inferior surfaces of the vertebral bodies. They are also attached to the anterior and posterior longitudinal ligaments. The disks are further attached to the heads of ribs two through nine in the thoracic spine.
- The outermost portion of the disk consists of fibrous tissues, called "Sharpy's fibers", and the other layers are white fibro cartilage.
- There are six functions attributed to the IVD's:
  - (1) they act as shock absorbers to the body;
  - (2) they attach the vertebral bodies together;
  - (3) they give shape to the vertebral column by forming the secondary curves;
  - (4) they are powerful ligaments;
  - (5) they separate vertebral bodies;
  - (6) they form the anterior wall of the intervertebral foramina.<sup>28</sup>

## Nerves

- Cranial nerves originate from the brainstem, and mainly control the functions of the anatomic structures of the head.
- Spinal nerve C1 is called the suboccipital nerve which provides motor innervation to muscles at the base of the skull.
- C2 and C3 form many of the nerves of the neck, providing both sensory and motor control. These include the greater occipital nerve which provides sensation to the back of the head, the lesser occipital nerve which provides sensation to the area behind the ears, the greater auricular nerve and the lesser auricular nerve.
- The phrenic nerve arises from nerve roots C3, C4 and C5. It innervates the diaphragm, enabling breathing. If the spinal cord is transected above C3, then spontaneous breathing is not possible.
- The last 4 cervical spinal nerves, C5 through C8, and the first thoracic spinal nerve, T1, combine to form the brachial plexus which innervates the arm and upper back. The first nerve off the brachial plexus is the dorsal scapular nerve, arising from C5 nerve root, and innervating the rhomboids and the levator scapulae muscles. The long thoracic nerve arises from C5, C6 and C7 to innervate the serratus anterior. The brachial plexus first forms three trunks, the superior trunk, composed of the C5 and C6 nerve roots, the middle trunk, made of the C7 nerve root, and the inferior trunk, made of the C8 and T1 nerve roots. The suprascapular nerve is an early branch of the superior trunk. It innervates the suprascapular and infrascapular muscles, part of the rotator cuff. The trunks reshuffle as they traverse towards the arm into cords. There are three cords. The lateral cord is made up of fibers from the anterior and middle trunk. The posterior cord is made up of fibers from all three trunks. The medial cord is composed of fibers solely from the medial trunk.
- The lateral cord gives rise to the following nerves: The lateral pectoral nerve, C5, C6 and C7



to the pectoralis major muscle, the musculocutaneous nerve which innervates the biceps muscle, and the median nerve partly. The other part comes from the medial cord.

- The posterior cord gives rise to the following nerves: The upper subscapular nerve, C7 and C8, to the subscapularis muscle of the rotator cuff, the lower subscapular nerve, C5 and C6, to the teres major also of the rotator cuff, the thoracodorsal nerve, C6, C7 and C8, to the latissimus dorsi muscle, the axillary nerve, which supplies sensation to the shoulder and motor to the deltoid muscle and the teres minor muscle, and the radial nerve, which innervates the triceps brachii muscle, the brachioradialis muscle, the extensor muscles of the fingers and wrist (extensor carpi radialis muscle), and the extensor and abductor muscles of the thumb.

The medial cord gives rise to the following nerves: The median pectoral nerve, C8 and T1 to the pectoralis muscle, the medial brachial cutaneous nerve, T1, the medial antebrachial cutaneous nerve, C8 and T1, and the median nerve partly. The other part comes from the lateral cord C7, C8 and T1 nerve roots. The first branch of the median nerve is to the pronator teres muscle, as well as the flexor carpi radialis, the palmaris longus and the flexor digitorum superficialis. The median nerve provides sensation to the anterior palm, the anterior thumb, index finger and middle finger. It is the nerve compressed in carpal tunnel syndrome, and the ulnar nerve originates in nerve roots C7, C8 and T1. It provides sensation to the ring and pinky fingers. It innervates the flexor carpi ulnaris muscle, the flexor digitorum profundus muscle to the ring and pinky fingers, and the intrinsic muscles of the hand (the interosseous muscle, the lumbrical muscles and the flexor pollicis brevis muscle. This nerve traverses a groove on the elbow called the cubital tunnel, also known as the funny bone. Striking the nerve at this point produces an unpleasant sensation in the ring and pinky fingers.<sup>29</sup>

## **II. Head**

### **Cervicogenic Headaches**

Post whiplash headaches or cervicogenic headaches have myriad causes. The straightening of the neck can cause the head to move forward thereby irritating the greater occipital and the lesser occipital nerves, causing headache. Also, cervical spinal joints at the levels of C2-C3 as well as the temporomandibular joint can refer pain to the head. Additionally, muscles can develop trigger points which can refer pain to the head.

### **Dizziness**

Dizziness occurs in 2 out of 10 people who have whiplash injuries. Common causes of dizziness include:

- Lack of movement at the C1, C2, and C3 levels.
- Janet Travell, M.D., a pioneer in trigger point therapy opined that spasm of the sternocleidomastoid muscles can cause dizziness.
- Trigger points in the rectus capitis posterior minor and major muscles. The rectus capitis minor has connections to the dura mater and can cause headaches as well.
- Problems with coordinating eye movements and neck movements can cause dizziness.
- BPV-Benign Positional Vertigo-this can happen when the small otoliths of the inner ear get dislodged.
- Kinking of the vertebral artery in the neck, which is a very rare phenomenon, can cause dizziness.

## Post Whiplash Disorders

### Cognitive Disorders

Many people experience problems thinking, concentrating, and / or remembering after a car accident. The most common causes are concussions and pain which can effect the way our brain processes information.

### Sleep Disorders

Insomnia is another problem after car accidents. Some patients can't sleep because of pain, while others experience nightmares of the accident.

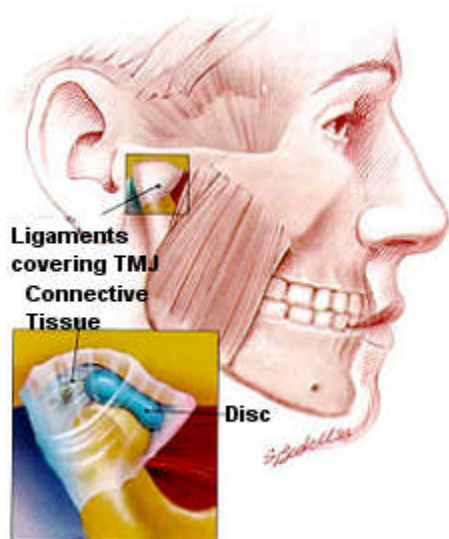
### Methods Utilized to Restore Normal Sleep Patterns

- Anti-inflammatories, pain relievers, narcotics, or muscle relaxers to reduce pain.
- Use of sleep inducing drugs like hypnotics or low dose anti-depressants.
- Biofeedback and relaxation techniques.
- Sleep with the room at a colder temperature setting.
- Learn comfortable sleep positions.
- Eliminate coffee, soft drinks, and other foods with caffeine before bedtime.

### Post Traumatic Stress Disorder

Post Traumatic Stress Disorder is a form of nervousness with a serious reaction to a tragic event such as a car accident. Symptoms include depression, nightmares, sleep disorders and headaches. Treatment is often the use of sedatives and psychotherapy.<sup>30</sup>

### Temporomandibular Joint Disorder



The temporomandibular joint is a common area of injury from a whiplash event. The most common symptoms include popping or cracking in the joint, pain in the jaw with chewing, and headaches.

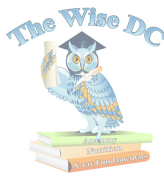
These symptoms are caused by:

- Sprains of the ligaments in the joint.
- Injury to the longus colli muscle which causes the sternocleidomastoid muscle to spasm and pull on the TMJ joint.
- Injuries to the disc inside the joint. These injuries are relatively rare, however, when it occurs it usually means longer term problems.<sup>31</sup>

## III. Muscle

### Basic Muscle Anatomy

Movement of the human body is dependent upon the interaction between the muscle, bone and joint systems. The human body contains more than 600 muscles. Skeletal muscle has contractile units that convert chemical energy into mechanical energy enabling the muscle to lengthen or shorten. Muscles cannot independently lengthen. They can lengthen only by contracting the



opposing muscles. When one muscle (the agonist) contracts, the opposite muscle (the antagonist) lengthens.

Tendons, which are strong, fibrous tissue, connect muscle to bone and facilitate muscle contraction. The attachment of the muscle at the proximal end of the bone (the end closer to the body) is considered the muscle's origin. The attachment at the distal end of the bone (the end farther from the body) is referred to as the muscle's insertion. The origin of the trunk muscles are always at the superior attachment, while the insertion is found at the inferior attachment.

Muscles do not move objects or weights. Instead, they function by moving the bones that rotate about the connective joints. These internal movements transfer a force through the body to the external object or resistance thereby causing the object or resistance to move. Muscles pull the bones, which act as a series of connected levers that move the body or outside objects in any direction desired. The joints hold the structure together and transmit forces through the bony levers of the body to the external environment while the bones provide structural support.

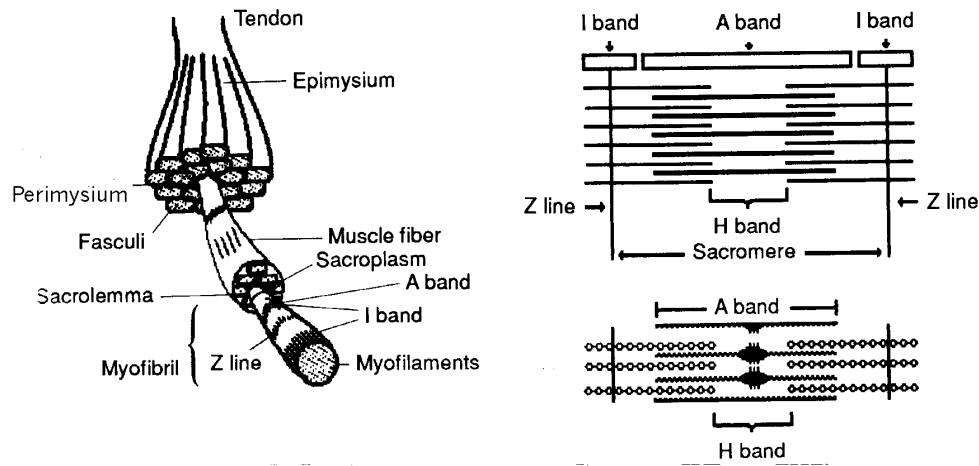
## **Muscle Physiology**

All movement depends upon the contractile, or shortening qualities of muscles acting upon the skeletal system. Joint movement occurs when there is sufficient force generated by the contraction of the muscle fibers crossing the joint.

Muscles are composed of many different structures. The structural unit of a muscle is the muscle fiber (the actual muscle cell). Each muscle fiber is composed of many nuclei. Muscle fiber size may range from .01 millimeter to .10 millimeters in diameter and from 1.0 millimeter to many millimeters in length. The muscle fiber is surrounded and bound together into bundles by connective tissue called endomysium. The bundles of muscle fibers are called fasciculi and are surrounded by white, fibrous connective tissue called perimysium. The external connective tissue that surrounds the entire muscle, made up of many fasciculi, is called epimysium.

Sarcolemma is a protective covering or membrane which surrounds the individual muscle fiber. Each muscle fiber has numerous myofibrils, which act as the contractile unit within the muscle fiber. Each myofibril is surrounded by a gel like substance called sarcoplasm (the protoplasm of the muscle fiber). In the sarcoplasm are mitochondria, small, rod--shaped bodies, often called the powerhouses of the cell because they are major sites of ATP production essential for muscular contraction.

Myofibrils are aligned in columns and have distinct markings, referred to as striations, in a definite repetitive pattern of light and dark bands. The repetitive pattern defines the sarcomere, which is the contractile unit of the muscle. The end of each sarcomere is bound by a Z--line.



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Variations in light and dark patterns are the result of the alignment of two small protein filaments, actin and myosin. Actin filaments are thinner than myosin filaments. Between each pair of Z--lines are a light band, known as the I--band (containing only thin actin filaments), a dark band, referred to as the A--band (the area where actin and myosin filaments overlap each other), an H--zone of slightly lighter contrast (which divides the middle of the A--band and contains only myosin filaments), and a second I--band. During muscular contraction the H--zone disappears as the actin filaments from the A--band extend into it. Actin and myosin filaments slide past one another when contraction of the fiber occurs.

The whole muscle--the bundles and the muscle fibers--is covered by layers of connective tissue that forms the tendon, which connect muscle to bone. When the muscle contracts and shortens, the force is transmitted through the tendon to the bone, thereby causing joint movement.

## Types of Muscle Fiber

Skeletal muscle fibers are classified according to the speed of their contraction period, as either being slow twitch or fast twitch. All skeletal muscles have slow and fast twitch fibers.

The **slow twitch, oxidative fiber** type, also known as Type I, is characterized by a slower rate of muscle contraction. This fiber primarily uses the oxygen energy system which replenishes ATP slowly. Slow twitch fibers are used mainly in aerobic endurance activities. Slow twitch fibers are often referred to as "**Red muscle**" because of the fibers reddish tint which is due to large amounts of myoglobin in the fibers and large amounts of red blood cells in the capillaries surrounding the fibers. Myoglobin acts as a reservoir for oxygen when the blood does not supply an adequate amount. Slow twitch fibers are fatigue resistant due to the ample blood and oxygen supply.

The **fast twitch, oxidative, glycolytic fiber** type, also known as Type II A, is characterized by a faster speed of contraction. This fiber type uses both the oxygen and lactic acid energy systems to replenish ATP and is used in both aerobic and anaerobic type activities.



The **fast twitch, glycolytic fiber** type, also known as Type II B, is characterized by a very fast speed of contraction. This fiber type primarily uses the lactic acid energy system and has the ability to use ATP rapidly. This fiber type is the largest of the three fiber types and is used primarily in fast, anaerobic type activities.

Fast twitch fibers are referred to as "**White muscle**" because of the fibers whitish tint due to the small myoglobin content in the fibers and the low number of red blood cells in the capillaries surrounding the fibers. Fast twitch fibers have extensive sarcoplasmic reticulum, which allows for rapid turnover of calcium ions in order for the contraction to be rapid. They also respond to neural stimulation rapidly and contain myosin molecules that break down ATP more rapidly than slow twitch fibers.

## **The Muscle Contraction Process**

There are two regulatory proteins, troponin and tropomyosin, which are part of the actin filament that function in keeping actin and myosin filaments from interacting with one another when the myofibril is in a state of relaxation. For contraction to occur, a nerve impulse travels along the sarcolemma sending a weak electrical charge over the length of the fiber. A series of tubules, known as T-- tubules, enter the muscle fiber through pores in the sarcolemma. T--tubules conduct the impulse from the sarcolemma toward the center of the fiber to the sarcoplasmic reticulum, which is a system of channels spread throughout the fiber. Calcium ions, stored in the sarcoplasmic reticulum, are then released and begin the contractile process. Calcium ions bind with troponin which blocks the function of tropomyosin, thereby allowing the actin and myosin filaments to interact and slide against one another. ATPase, an enzyme located on the cross--bridges of the myosin filament, is then freed to act upon ATP causing it to break down into ADP (adenosine diphosphate) and energy. Actin and myosin filaments slide past one another due to the pulling action of the cross--bridges that reach out from myosin filaments and attach themselves to the actin filament. This action takes place simultaneously in thousands of muscle fibers causing forceful pull on your tendons which initiates skeletal movement. The contraction is complete when the myosin filaments reach the Z-- lines.

## **Vertebral Column Muscles**

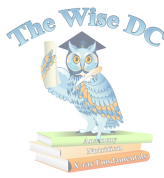
There are over 70 muscles directly attached to the vertebral column. They are divided into groups according to their layer position. Any of these muscles can potentially sustain injury as the result of a whiplash motion.

Layer I (superficial layer of muscle)

- Trapezius – originates at the external occipital protuberance and inserts at the lateral clavicle, median margin of the acromion and the scapular spine.
- Latissimus dorsi – originates in the lumbar aponeurosis and the spinous processes of T6-T12, L1-L5 and the sacral tubercles. The insertion of the latissimus dorsi is at the intertubercular groove of the humerus.

Layer II





- Rhomboid major – originates at the spinous processes of T2-T5 and inserts at the inferior portion of the scapular spine.
- Rhomboid minor – originates at the spinous processes of C7-T1 and inserts at the base of scapular spine.
- Levator scapulae – originates at the transverse processes of C1, C2 and posterior transverse tubercles of C3 and C4, and inserts at the medial border of the scapula.

#### Layer III

- Splenius capitis – originates at the spinous processes of C7, and T1-T4 and inserts at the mastoid process and occiput.
- Splenius cervicis - originates at the spinous processes of T3-T6 and inserts at the transverse processes of C1-C4.
- Serratus posterior superior – originates at the spinous processes of C7 – T3 and inserts at the superior borders of the 2<sup>nd</sup> through the 5<sup>th</sup> ribs.
- Serratus posterior inferior – originates at the spinous processes of T11-T12 and L1-L2 and inserts at the inferior border of the last 4 ribs.

#### Layer IV Erector Spinae Group / Sacrospinalis

- Iliocostalis group – (lateral column of muscle).
- Longissimus group – (intermediate column of muscle).
- Spinalis group – (medial column of muscle).

Layer V Deep Layer Groups – this group is found deep to the erector spinae group and is comprised of the transversospinal, suboccipital, prevertebral / anterior vertebral and lateral vertebral muscles.

### Transverso Spinae Group

This group receives its name because the muscles generally pass upwards and medially from the transverse processes to the spinous processes. The five muscles in this group include the following:

- **Semispinalis**—This muscle has three components:

**thoracis**— Its origin is the transverse processes of T7 through T12. Its insertion is into the spinous processes of C6 and C7 and T1 – T4.

**cervicis**—It's origin is from the transverse processes of T1-T6 and the articular processes of C4-C7. It inserts into the spinous processes of axis through C5.

**capitis**—Its origin is the transverse processes of T1-T6 and the articular processes of C4-C6. It inserts into the medial impression between the superior and inferior nuchal line.

The action of the semispinalis is to extend the spinal column and head, respectively, and to rotate them to the opposite side.

**Multifidus**—This muscle fills the groove between the spinous processes and the transverse processes.

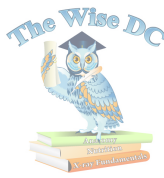
The action of the multifidus is to assist in extension, lateral flexion, and rotation of the vertebral column in their respective regions. It also assists in pelvic extension and lateral movement.

- **Rotatores**—The rotatores are deep to the multifidus and for the most part are continuous with multifidus fibers.

Their origin is the transverse processes of all lumbar and thoracic vertebrae and C3-C7.

Rotatores extend superior and insert into the laminae of either the vertebrae above (rotatores brevis), or the second vertebrae above (rotatores longi). The rotatores are best developed in the thoracic spine.

These muscles extend the vertebral column and rotate it to the opposite side.



- **Interspinales**—These muscles are short and are found at each of the interspinous spaces. The action of the interspinales is to extend the vertebral column.

- **Intertransversarii**—These muscles originate and insert between adjacent vertebral transverse processes.

The action of the intertransversarii is to bend the vertebral column laterally.

### Suboccipital Group

- **Rectus capitis posterior major**—its origin is at the spinous process of the axis and it inserts into the lateral portion of the inferior nuchal line of the occiput and the surface area below the inferior nuchal line. This muscle extends and rotates the head to the same side.
- **Rectus capitis posterior minor**—its origin is the posterior tubercle of the atlas' posterior arch and it inserts into the medial portion of the inferior nuchal line and the surface between it and the foramen magnum. The action of this muscle is extension of the head.
- **Obliquus capitis superior**—its origin is from the superior surface of atlas' transverse process and it runs obliquely up and medial-ward and is inserted between the superior and inferior nuchal lines of the occiput, lateral to the semispinalis capitis insertion. The action of the superior oblique muscle is extension and lateral flexion of the head.
- **Obliquus capitis inferior**—this muscle is the larger of the two obliques. From its origin at the spinous process of the axis it runs slightly upward and lateral to insert at the transverse process of the atlas where the superior oblique originates. The action of the inferior oblique muscle is to rotate the atlas (and subsequently the head) to the same side.

### Prevertebral / Anterior Vertebral Group

In general, anteriorly attached muscles will flex the vertebral column, unless acting unilaterally. The muscles in this group are: longus colli, longus capitis, rectus capitis anterior, and lateral rectus capitis.

- **Longus colli**—This muscle is located between the atlas and T3 at the anterior. It is narrow at each extremity and wide at its center.

The action of the longus colli muscle is flexion of the cervical spine and slight cervical rotation. The longus colli muscle assists in rotation and cervical flexion and helps to support your head as you get up from lying down. Trigger points in this muscle can cause headaches in the temples and dizziness and imbalance. This muscle is also closely tied to the temporomandibular joint and is often sore in patients with TMJ syndrome. In patients who develop a forward head posture, this muscle can become overworked.<sup>33</sup>

- **Longus capitis (Rectus capitis anterior major)**—its origin is the anterior tubercles of the transverse processes of C3-C6. Its insertion is the basilar process of the occipital bone near the pharyngeal tubercle. The action of the longus capitis is to flex the head.

- **Rectus capitis anterior – (Rectus capitis anterior minor)** – It is located immediately under the superior portion of the longus capitis muscle. It originates at the anterior surface of the lateral mass of the atlas and from atlas' transverse process near its base. It inserts into the inferior surface of the basilar process just anterior to the foramen magnum. The action of the rectus capitis anterior is flexion of the head.

- **Rectus capitis lateralis**—its origin is from the superior surface of the transverse process of the atlas. It inserts into the inferior surface of the jugular process of the occiput. The action of the lateral rectus is lateral flexion of the head.<sup>34</sup>

### Lateral Vertebral Group<sup>35</sup>

There are three muscles in this group: scalenus anterior, medius, and posterior.

**Scalenus anterior**—this muscle lies deep to the sternocleidomastoideus. The origin of the anterior scalene is from the anterior tubercle of the transverse processes of the third through sixth cervical vertebrae. The insertion is by a very narrow tendon into the scalene tubercle on the inner border of the first rib into the ridge located on the top surface of the rib near the subclavian groove.

The action of the scalenus anterior is to laterally flex and rotate the cervical spine and to raise the first rib.

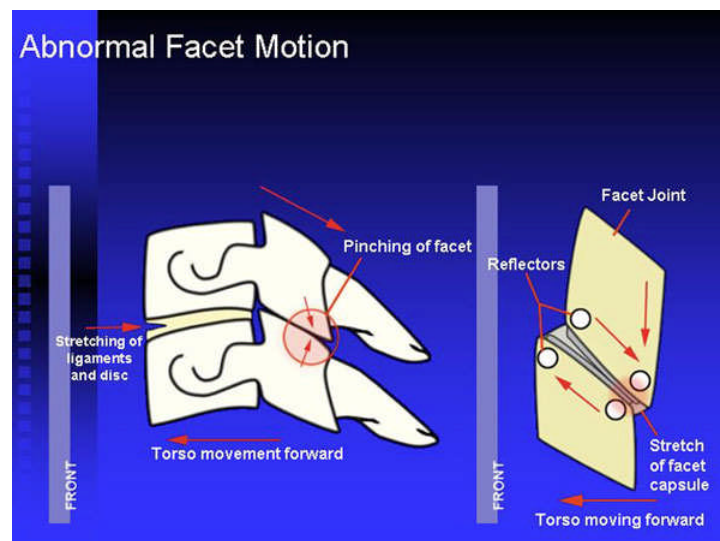
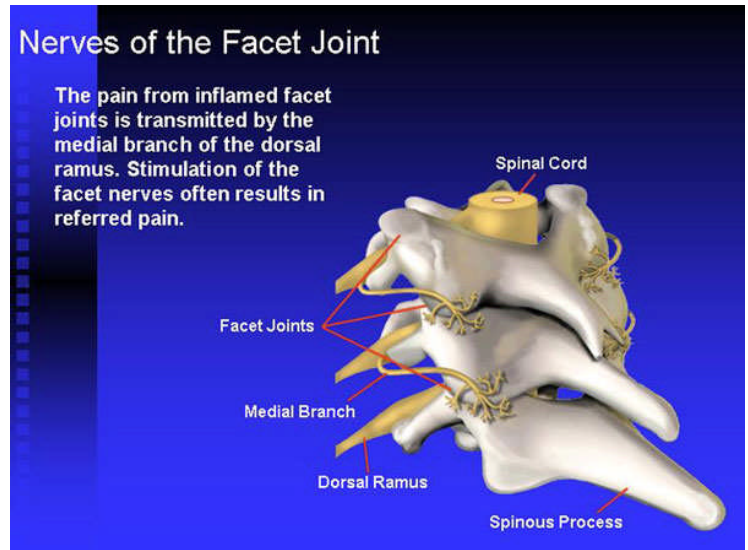
**Scalenus medius**—the medius is the longest of the scalene muscles and has its origin at the posterior tubercles of the transverse processes of axis through C7. Its insertion is into the superior surface of the first rib, between the tubercle and the subclavian groove. The action of the medius is flexion, lateral flexion, rotation of the cervical vertebral column, and elevation of the first rib.

**Scalenus posterior**—this is the smallest and deepest of the three lateral vertebral muscles. It originates from the posterior tubercles of the transverse processes of C5 – C7. It inserts into the outer surface of the second rib behind the attachment of the serratus anterior. The action of the posterior scalene is slight lateral flexion, rotation of the cervical spine, and elevation of the second rib.<sup>36</sup>

#### IV. Facet Joints

Facet pain is usually worse in the morning or with less activity and lessens as the day goes on. Facet pain is described as deep, sharp, and often aching. The C2-C3 facet joint can refer pain into the back of the head while the C6-C7 joint more commonly sends pain to the shoulder blade area. Facet pain increases when the facet joint is compressed.

Facet pain after whiplash can weaken the muscles that help stabilize the spine. Damage to the facet causes an inhibitory signal to be sent which blocks the normal signal sent by the disc to the multifidus muscle thereby causing increased facet pain.<sup>37</sup>



## V. Cervical Ligaments

### Atlanto-Occipital Ligaments

The ligaments in the atlanto-occipital articulation are as follows:

- **Anterior atlanto -occipital membrane**—This ligament attaches from the external surface of the anterior arch of atlas and runs up to the anterior margin of the foramen magnum. It is a direct continuation of the anterior longitudinal ligament.
- **Posterior atlanto -occipital membrane**—This ligament attaches from the posterior arch of atlas to the posterior margin of the foramen magnum. The medial portion is firmly attached to the posterior arch, but its lateral portion arches over the superior.
- **Lateral atlanto - occipital ligament (anterior oblique ligament)**—The lateral ligaments run from the transverse process of the atlas up to the jugular process of the occiput.
- **Articular capsule (capsular ligament)**—These ligaments enclose the articular surfaces and are lined with a synovial membrane which produces synovial fluid that lubricates the joint.

### Occipito-Axial Ligaments

- **Membrana tectoria** —This is a broad sheet-like ligament which is a direct continuation of the posterior longitudinal ligament.
- **Alar ligament (check ligament/odontoid ligament)**—These ligaments attach from the apex of the dens (there are two, one on each side of the dens' apex) and run upward to the medial surface of each condyle on the occiput. These ligaments “check” the degree of head rotation on the axis.
- **Apical ligament (suspensory ligament)**—This ligament is singular and runs from the tip of the odontoid process to the anterior margin of the foramen magnum. It is the remains of the embryonic notochord. The remainder of the notochord persists in adults as the nucleus pulposus in the intervertebral disks below the axis level.
- **Cruciate ligament** – This ligament has three components.
- **Transverse ligament of atlas**—This is found in the atlanto-axial articulation and runs between the medial surfaces of the lateral masses.

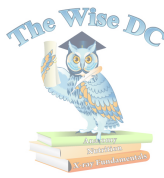
**Cranial crus**—Beginning at the central portion of the transverse ligament of atlas, this band of fibers runs upward to the anterior margin of the foramen magnum.

**Caudal crus**—This begins at the central portion of the transverse ligament of atlas, runs inferiorward and attaches at the center of axis' posterior body.

The cruciate ligament has a “cross-like” appearance when all three components are considered.

### Atlanto-Axial Ligament

- **Anterior atlanto-axial**—This ligament runs from the anterior surface of the body of axis to the anterior portion of the atlas' anterior arch. It is a continuation of the anterior common ligament upwards and continues upward past atlas as the anterior atlanto -occipital.
- **Posterior atlanto -axial**—These ligaments run upward from the laminae of the axis to the posterior arch of the atlas.
- **Accessory ligament**—These ligaments run from the medial surface of each lateral mass downward to the posterior surface of the body of axis. Often times their point of attachment is the base of the dens.
- **Transverse ligament of atlas**—This is a strong ligament which runs from the tubercle on each lateral mass and arches across the neural ring of the atlas to hold the odontoid process in place against the fovea dentalis of the atlas. The transverse ligament does not attach to the odontoid process. There is a small synovial pocket between the transverse ligament and the



odontoid process which allows proper rotatory movement of the atlas around the odontoid process.

- **Capsular ligament**—These articular capsules firmly attach to the articular surfaces and surrounding osseous structures and are lined with a synovial membrane.<sup>38</sup>

### Vertebral Body Ligaments

- **Posterior Longitudinal Ligaments** (posterior common ligament) – This ligament attaches from the axis and runs downward to the posterior surface of the first sacral segment. This ligament is widest in the cervical region, attaches directly to the discs and a small portion of the vertebral bodies, and is found inside the neural canal in close contact with the spinal dura mater.
- **Intervertebral Discs** – There are 23 vertebral discs which are responsible for approximately 25% of the length of the adult spine (18cm).

### Spinous Process Ligaments

- **Supraspinous Ligament** – Extends from C7 spinous process to the first sacral tubercle.
- **Interspinous Ligament** – Thin membrane like ligament.
- **Ligamentum Nuchae** – This ligament extends from the occiput to L5.

### Lamina, Transverse Process and Articular Process Ligaments

- **Ligament Flava** – is the only true elastic ligament of the body attaching from the lamina above to the lamina below.
- **Intertransverse Ligament** – recognizable only in the lumbar region with scattered fibers found in the cervical and thoracic spines.

### Anterior Longitudinal Ligament

**Anterior longitudinal ligament (anterior common ligament)**— This ligament attaches the vertebral bodies at the front. It begins at the axis and runs down to the first sacral segment as it passes each IVD it firmly attaches to each. This ligament is important because it can be injured in severe rear end accidents. When this ligament tears it can cause anterior disc herniations.<sup>39</sup>

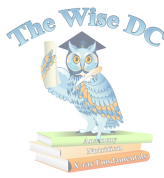
### Stages of Healing for Musculoskeletal Soft Tissues

The healing process is categorized into progressive stages that involve various cellular responses at particular timeframes.

**I. Acute inflammatory Stage.** This initial stage of response to injury lasts up to 72 hours and consists of two distinct stages. The first stage is called active congestion, which lasts for the first 24-48 hours and involves the initial cellular responses, resulting in the classic signs of inflammation (i.e., pain, swelling, redness and heat). The goal of clinical management during this stage of the healing process is to reduce or eliminate inflammation. The use of rest, ice, compression and elevation are common treatment methodologies. The second stage, which lasts from 24-72 hours, is the passive congestion phase of healing. During this stage membrane osmolarity is controlled but the pain and swelling may still persist. The goal of clinical management in this phase is to increase the circulation to the area of the injury and to remove metabolites from the tissues. Treatment methodologies include alternating hot and cold therapies, massage, range of motion exercises and passive stretching.

**II. Repair Stage.** The repair stage lasts from 72 hours to 6 weeks and is characterized by the production, synthesis and deposition of the protein collagen. Collagen helps to regenerate





damaged tissue. Granulocytes remove the cellular debris and capillaries form to bring oxygenated nutrients to the involved area. The oxygen and nutrients activate fibroblasts, which manufacture and secrete collagen. The collagen scar secreted by the fibroblasts will replace the damaged musculoskeletal soft tissue that has been injured from trauma.

During the repair stage the fibers of the collagen are not fully oriented in the direction of tensile strength, and the collagen is of a mechanically inferior quality.

**III. Remodeling Stage.** This stage lasts from 3 weeks to 12 months or more depending upon the severity of the injury. During this stage the collagen scar is remodeled to increase the functional capabilities of the tissue. The goal of clinical management is to improve the quality, orientation and tensile strength of the collagen tissue fibers. Clinical management can include manipulation, rehabilitative exercise protocols and passive physiotherapy such as ultrasound and massage.<sup>40</sup>

### **Conservative Chiropractic Rehabilitative Procedures**

1. Manual or mechanically assisted adjustments.
  - A. Minimum time for favorable response: 30 sessions.
  - B. Frequency: Daily for up to 2-4 weeks decreasing to 3 times per week for up to 16-24 weeks.
  - C. Treatment objectives:
    - Static alignment of global body positions.
    - Functional capacity of related structures such as increased mobility / flexibility, strength, endurance, etc.
    - Reduced stress and/or strain of involved intra and extra-articular structures including muscle, ligament, bone, tendon, cartilage, neural and/or vascular tissue.
    - Management of disability or symptoms which are attributable to adverse spinal mechanics which impair activities of daily living.
2. Manual therapy including therapeutic massage, joint manipulation and mobilization.
  - A. Minimum time for favorable response: 16 treatments.
  - B. Frequency: 2-5 treatments per week for first 2 weeks, decreasing to 1-3 treatments per week followed by 1-2 treatments per month for a total of 2-4 months.
3. Thermal treatment consisting of application of surface or deep cooling or heating procedures.
  - A. Minimum time for favorable response: 14 treatments.
  - B. Frequency: Daily for up to two to three weeks decreasing to 2-3 times per week after the first month.
  - C. Maximum duration: Up to 12 months.
4. Restriction of activity, i.e. bed rest and limited activities.
  - A. Minimum time for favorable response: 1-2 days.
  - B. Frequency: Continuous.
  - C. Maximum duration: 7 days—prolonged immobilization and activity restriction are counterproductive to a patient's recovery.
5. Corrective traction, performed to reduce subluxations and to restore the cervical lordosis.
  - A. Minimum time for favorable response: 8-10 weeks.
  - B. Frequency: Daily to 3 times per week.
  - C. Maximum duration: Only one clinical experiment has been performed in which the treatment protocol utilized daily applications for 10-14 weeks. The authors, Harrison, Murphy and Trojanovich opined that maximum usage could be up to 12 months.
6. Supports, braces or other movement restricting devices.
  - A. Minimum time for favorable response: 1-3 days.
  - B. Frequency: Intermittent use to assist in management during times of increased physical stress.



- C. Maximum duration: 4-6 weeks or as needed by physical demand.
- 7. Rehabilitative exercise to improve strength and flexibility and to reduce postural displacements through neuromuscular reeducation.
  - A. Minimum time for favorable response: 2-4 weeks.
  - B. Frequency: Daily to 3 times per week.
  - C. Maximum Duration: Up to 12 months and thereafter on an as needed basis.
- 8. Patient education to promote an understanding of treatment goals, and active patient participation thereby enhancing a successful clinical outcome.

### Foreman And Croft's Prognosis Scale

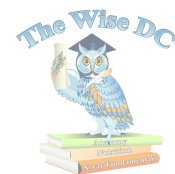
Whiplash researchers, Foreman and Croft, devised a numerical scale to predict patient prognosis in the event of whiplash injury.

The numerical scale is as follows:

Point values assigned by history and physical examination findings		
Category	Findings	Point Value
1	Subjective symptoms only	10
2	Symptoms & loss of range of cervical motion	50
3	Subjective symptoms, loss of motion, and objective neurological loss	90

Modifiers and their assigned point values.	
Modifier	Point Value
Canal Size 10-12mm	20
Canal Size 13-15mm	15
Kyphotic Curve	15
Fixated Segments	15
Loss of Consciousness	15
Military Neck	10
Preexisting Degeneration	10

Prognosis categories and likely residual disabilities.	
Prognosis Category / Point Total	Prognosis / Residuals
Group 1 (10-30 points)	Excellent – Mild muscle pain and / or headaches
Group 2 (35-70 points)	Good – Occasional mild to moderate neck pain
Group 3 (75-100 points)	Poor – Potential for future neurological complications
Group 4 (105-125 points)	Guarded – Likely future or persistent neurological deficits
Group 5 (130-165 points)	Unstable – No likely improvement – Probable future surgical intervention



## Head Trauma

### Concussion Grading

#### **Grade 1 / First Degree Concussion**

- No actual loss of consciousness.
- Blurring of consciousness lasting less than 10-20 seconds. Minimal or no signs are present.
- The only neurologic deficit is a brief period of post-traumatic amnesia lasting less than 30 minutes.
- EEG, CT or MRI are usually not necessary after a mild concussion. If post-concussion syndrome occurs these studies should be done.

#### **Grade 2 / Second Degree Concussion:**

- Blurring or loss of consciousness lasting 20 seconds to 1-2 minutes. Minimal to moderate symptoms and signs are present.
- Will rarely occur without a loss of consciousness. Typically there will be a protracted period of post-traumatic amnesia lasting over 30 minutes and less than 24 hours.
- Generally overnight admission for observation and CT scan if necessary.

#### **Grade 3 / Third Degree Concussion:**

- Loss of consciousness lasting more than five minutes.
- There will be loss of consciousness with a sustained period of post-traumatic amnesia lasting longer than 24 hours.<sup>42</sup>

## Orthopedic Evaluation of the Cervical Spine

**Orthopedics** — Orthopedic tests are effective tools utilized to formulate a diagnostic impression of a patient who presents with pain. The purpose of an orthopedic test is to introduce a forceful movement which is designed to reproduce the pain syndrome. Each orthopedic test consists of **three** essential components, ① the mechanisms of the test, ② what constitutes a positive finding and ③ what a positive finding indicates. The clinician must assess contraindications *before* submitting the patient to a provocative test.

#### **Considerations**

- Frequently tests which are mechanically the same or contain similar maneuvers have different names or different indications.
- While reviewing records take into consideration that teachers and authors suggest slight variations in procedures.
- The accuracy and validity of any test will depend upon the stage and severity of the condition.

**Range of Motion Testing** — is a *standard part of all inter-disciplinary* assessments. Normals may vary slightly and are subject to interpretation depending upon stage and severity of the condition. All orthopedic assessments must include a range of motion assessment if practical. In cases of severe tissue damage this procedure may be delayed for several days following an acute trauma.

#### **Cervical Spine Range of Motion Norms-**

Flexion	45°
Extension	55°
Lateral Bending	45°
Rotation	70°



## **Most Commonly Used Orthopedic Tests of the Cervical Region**

**Cervical Compression** — place both hands on the top of the patient's head and gradually apply a downward pressure. Radiating pain is a positive, suggestive of nerve root compression.

### **Variations of Cervical Compression Testing**

- Jackson's Maneuver — adds a lateral flexion component to the compression test.
- Cervical rotation with compression.
- Maximum cervical compression — incorporates lateral flexion, rotation and extension and may include physician assisted compression.
- Spurling's — incorporates maximum cervical compression with a sharp tap "punch downward".

**Bokody's Sign** — reduction in radicular pain when the patient's *hand is placed above their head* is a positive sign indicative of nerve root compression.

**Cervical Distraction** — *gently lift* the patient's head. Positive findings include pain or relief. Pain is suggestive of muscular/ligamentous injury, i.e., sprain/strain. Relief is indicative of nerve root compression.

**Shoulder Depressor, AKA Dural Sleeve Stretch** — application of a *downward pressure to one shoulder with simultaneous lateral flexion* of the head to the opposite shoulder. A positive finding includes radiating pain and is indicative of fibrotic dural sleeve adhesions. Radiating pain must be present for a positive finding.

**Soto-Hall** — with one hand placed on the patient's sternum, *passively flex* the patient's head to their chest. Pain indicates possible sprain/strain injury or cervical fracture (especially compression fracture).

**Swallowing Test** — instruct the patient to *swallow*. A positive test may indicate paravertebral mass or swelling such as in the case of Forester's Disease, AKA Diffuse Idiopathic Skeletal Hyperostosis or brain stem lesion. A thorough history will determine whether the patient had sustained a direct trauma to the anterior compartment of the neck.

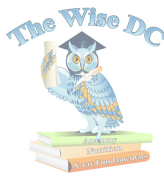
**Lhermitte's Sign** — this test is positive when the patient experiences "*electric*" or "*shock-like*" sensations during cervical flexion. For example: this sign may be revealed during range of motion testing, performing Soto-Hall's Test, etc. It could be indicative of a cord lesion such as multiple sclerosis or meningeal irritation or possibly associated with infection.

**Discogenic Assessment** — this test is *designed to reveal complications* associated with intrathecal pressure, i.e., Dejerine's Triad, Nafziger's Test, a distinction must be made between these findings and those associated with the cervical compression testing maneuvers.

## **Neurological Evaluation of the Head, Spine and Extremities**

### **Neurological Testing**

- Deep tendon reflexes: Bicep (C5 musculocutaneous nerve); Brachioradialis (C6 radial nerve); Tricep (C7 radial nerve); Patellar (L4 femoral nerve); Achilles (S1 tibial nerve).
- Superficial reflexes: upper/lower abdominal (T 7-T12); plantar response - tibial nerve (L4, L5, S1 and S2).
- Muscle strength grading: hip flexors (L2, L3); hip extensors (L4, L5); knee extensors (L3, L4); knee flexors (L5, S1); ankle extensors (L4, L5); ankle flexors (S1, S2).
- Pathological reflexes—Babinski—the single most important pathological sign in neurology. Stroke the sole of the foot. With a positive Babinski you will see extension of the big toe and fanning of the toes. Normal is dorsiflexion of the big toe and flexion of the toes.
- The following tests will elicit a Babinski sign;
- Chaddock-Stroke the lateral malleolus.
- Oppenheim- Stroke downward on the anterior tibia.



- Gordons-Squeeze the calf muscle.
- Schaffers – Squeeze the achilles tendon.
- Rossolimo's-Tap the ball of the foot. A positive Rossolimo test will cause dorsiflexion of the big toe and flexion of the toes.

## **Cranial Nerve Evaluation**

Cranial Nerve I (Olfactory Nerve) — is a sensory nerve which controls the ability to smell.

Cranial Nerve II (Optic Nerve) - is a sensory nerve which controls vision.

### Optic Nerve Testing

1. Visual acuity is a test of central vision. A Snellen chart is used to test visual acuity. Position the patient 20 feet from the chart and determine the smallest line of print in which half the letters can be identified. Visual acuity is expressed as a fraction. The numerator is the distance of the patient from the chart and the denominator is the distance at which the normal eye can read all of the lines of letters (e.g. 20/20).
2. Confrontation Test - the patient and the examiner sit across from one another. The patient covers their left eye and the examiner covers their right eye. The examiner brings a pencil into the patients field of vision from several directions and asks the patient to indicate when the object appears. A normal person looking straight ahead should be able to detect a moving object at a 90° angle.
3. Accommodation Test - Accommodation is the process by which a clear visual image is maintained as the gaze is shifted from a distant to a near point. The **three** components of the reaction are:
  - Convergence of the eyes.
  - Pupillary constriction.
  - Thickening of the lens through contraction of the ciliary muscles.

Only the first two are visible to the examiner.

4. The Light Reflex Test -
  - Direct reflex - the pupil constricts upon exposure to light.
  - Indirect or consensual reflex – the pupil constricts when the opposite eye is exposed to light.

Cranial Nerve III (Oculomotor Nerve) - motor to pupillary constriction; controls elevation of the upper eyelid; controls extraocular movements of the eye up and inward, up and outward, inward and down and outward.

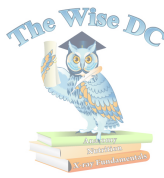
Cranial Nerve IV (Trochlear Nerve) — motor nerve which controls downward, inward movement of the eye. Responsible for conjugate eye movements (eyes moving together).

Cranial Nerve V (Trigeminal Nerve) - is a sensory and motor nerve. The sensory portion of the nerve has **three** divisions to include the following:

1. Ophthalmic.
2. Maxillary
3. Mandibular.

The Trigeminal Nerve controls motor function of the temporal muscles and masseter muscles (muscles of mastication). The nerve also controls lateral movement of the jaw.

Cranial Nerve VI (Abducens Nerve) — is a motor nerve which controls lateral deviation of the eye.



Cranial Nerve VII (Facial Nerve) - Motor - muscles of the face, forehead and around the eyes and mouth which controls facial expressions. Sensory - taste on the anterior 2/3 of the tongue. Asking the patient to blink would be an assessment of the facial nerve.

Cranial Nerve VIII (Acoustic, also known as the Vestibulo/Cochlear Nerve) - Hearing (cochlear division) and balance (Vestibular division).

Cranial Nerve IX (Glossopharyngeal) - Sensory - of the posterior eardrum, ear canal, pharynx, and taste sensation of the posterior 1/3 of tongue. Motor - pharynx muscles (muscles of swallowing).

Cranial Nerve X (Vagus Nerve) - Sensory - pharynx and larynx. Motor - to the palate, pharynx and larynx. The gag reflex is a test of this nerve.

Cranial Nerve XI (Spinal Accessory Nerve) - Motor to the upper trapezius and sternocleidomastoid muscle. Test by having the patient turn their head and shrug their shoulders against resistance.

Cranial Nerve XII (Hypoglossal Nerve) — Motor to the muscles of the tongue.

### **Quick Cranial Nerve Assessment at the Scene of the Accident**

If the injured person's pupils are unequal in size then have them transported to the emergency room immediately.

#### **Steps:**

1. Ask the injured person to follow your finger from a distant point to their nose. Look for accommodation, convergence of the eyes and pupillary constriction. (Cranial Nerve II, Optic Nerve).
  2. Perform the six cardinal fields of gaze test. (Cranial Nerve III, Oculomotor; Cranial Nerve IV Trochlear; and Cranial Nerve VI Abducens).
  3. Take three fingers and place them on the person's face at the level of the eye (ophthalmic branch), mouth (maxillary branch) and jaw (mandibular). Ask them if they feel your touch. (Cranial Nerve V, Trigeminal).
  4. Ask the injured person to blink. (Cranial Nerve VII, Facial).
  5. Ask the injured person to swallow (Cranial Nerve IX, Glossopharyngeal).
  6. Ask the injured person to stick out their tongue (Cranial Nerve XII, Hypoglossal), and check the gag reflex. (Cranial Nerve X, Vagus).
  7. Ask the injured person to shrug their shoulders. (Cranial Nerve XI, Spinal Accessory).
- Cranial Nerve VIII, Vestibulo / Cochlear Nerve, is assumed if the injured person hears you and responds to your questions.

### **Quick Assessment of the Extremities at the Scene of the Accident**

#### **Upper Extremity Sensory Assessment**

- Radial Nerve - dorsum of the thumb and index finger webspace.
- Ulnar Nerve - tip of the fifth digit.
- Median Nerve - top of the second and/or third digit.
- Musculocutaneous Nerve - extensor aspect of the forearm.
- Axillary Nerve - lateral aspect of the upper arm.



#### Upper Extremity Motor Assessment

- Radial Nerve - extension of the thumb.
- Ulnar Nerve - Adduction of the thumb, i.e., thumb to little finger.
- Median Nerve - flexion of the first joint of the thumb.

#### Lower Extremity Sensory Assessment

- Peroneal Nerve - dorsum of the foot.
- Tibial Nerve - back of the heel.
- Saphenous Nerve (from the femoral nerve) - medial malleolus.

#### Lower Extremity Motor Assessment

- Peroneal Nerve - dorsiflexion of the great toe. (L-5 nerve root).
- Tibial Nerve - plantar flexion of the great toe.

### **How to Determine A Brachial Plexus Lesion From A Nerve Root Lesion**

#### **Characteristics of a Brachial Plexus Lesion**

- Numbness and burning of the entire arm, hand and fingers.
- Sensation loss over two to four dermatomes.
- Complete transient paralysis of the arm.
- Tenderness over the posterior neck.
- Increase in symptoms with passive movement of the head and neck to the opposite side.
- Symptoms do not occur with downward pressure on the head with the chin in the supraclavicular fossa on the same side as the lesion.

#### **Characteristics of a Nerve Root Lesion**

- Numbness and burning are confined to one or more definable dermatomes.
- Sensation loss is confined to a definable dermatome.
- Partial transient paralysis of the arm.
- No tenderness over the brachial plexus.
- Tenderness over the posterior neck.
- Hyperflexion, extension, or lateral flexion of the neck to the same side as the symptoms causes symptoms.
- Symptoms occur with downward pressure on head.

### **Upper and Lower Motor Neuron Analysis**

- **Upper Motor Neuron** - includes everything from the brain down to the spinal cord except the anterior horn. Structures include the brain, brainstem, cerebellum, white matter and the posterior and lateral horns of the spinal cord. Upper motor neurons modify and inhibit the effect of the reflex arc. Examples of upper motor neuron lesions include stroke, tumor, Parkinson's, and cerebral palsy.
- **Lower Motor Neuron** - these neurons are found in the anterior horns and their axons, which may originate from the brainstem and spinal cord, the myoneural junction, or the muscles innervated. Examples of causes of lower motor neuron lesions include trauma, polio, nerve compression, tumor of peripheral nerves, subluxation and infection. Lower motor neuron lesion diseases include Lou Gehrig's (amyotrophic lateral sclerosis) and muscular dystrophy.



## Comparison

	Lower Motor Neuron Lesion	Upper Motor Neuron Lesion
Paralysis / Paresis	Flaccid	Spastic
Reflexes	Decreased (Hyporeflexia)	Increased (Hyperreflexia)
Superficial Reflexes	Decreased or Absent	Decreased
Pathological Reflexes	Absent	Present
Clonus	Absent	Present
Tonicity	Hypotonicity	Hypertonicity
Atrophy	Present	May be present due to disuse atrophy
Fasciculations	Present	Absent

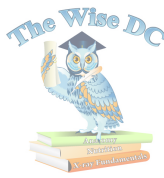
## Diagnostic Testing Procedures Utilized Following a Motor Vehicle Accident

### Plain Film Radiographs

- Conventional plain film radiography is the most widely utilized skeletal imaging method.
- The natural contrast of X-ray images is derived from the five radiographic densities - air, fat, water, bone, and metal.
- There is an absolute necessity of having a minimum of two views perpendicular to each other. These should be supplemented with additional projections, such as oblique, angulated, or stress studies, as clinically indicated.
- A routine cervical series of X-rays involves three views: A-P lower cervical, A-P open mouth cervical, and lateral cervical. A Davis series also includes obliques, flexion, and extension views and is considered the gold standard in cases of cervical whiplash.
- A routine thoracic series of X-rays involves two views: A-P thoracic and lateral thoracic.
- A routine lumbar or lumbosacral series of X-rays involves two to three views: A-P lumbar and lateral lumbar, and a lateral L5-S1 spot shot is often elected.
- Considerable conflict has arisen in recent times as to the indications for when skeletal radiography should be obtained as concerns for radiation safety, public health, and rising health costs have gained momentum. Guidelines have been developed to assist in the imaging decision-making process.
- Routine radiography is inappropriate [E.L. Maurer. (Article) "Biological Effects of Diagnostic X-ray Exposure" *American Journal of Chiropractic Medicine*, 1988, and W.K. Sinclair. (Article) "Trends in Radiation Protection" *Health Physics*, 1988.]
- The routine use of repeat X-ray studies is not considered medically necessary.
- With the exception of providing analysis of X-ray films performed elsewhere, a distinct X-ray interpretation charge is not customary.

### Applications:

- Useful in the detection of skeletal abnormalities such as neoplasms, traumatic injury, infection, and anomalies.
- Recognition of a definitive diagnosis is frequently possible.
- X-ray imaging provides pivotal information as to what additional imaging modality may be indicated or contraindicated.
- X-ray imaging offers comparison of changes of a disease process over time.



## **Computerized X-Ray Tomography - CT Scan**

- Most commonly used in conjunction with plain film X-ray findings.
- CT scanning is not a screening procedure.
- Capable of detecting traumatic lesions of the musculoskeletal system particularly of complex anatomical structures, flat bones, vertebrae, pelvis, ankle, wrist, and shoulder.
- The use of CT is indicated when radiographs are equivocal or when suspected clinical findings are not substantiated by the present plain film study.
- CT is the imaging modality of choice for visualization of calcified lesions of periosteum or soft tissues.
- Infection as seen in discitis, and osteomyelitis are well visualized.
- In the evaluation of soft tissue neoplasm CT scanning best evaluates the osseous characteristics and calcified regions of a neoplasm. This procedure is able to detect bony changes of a neoplasm earlier than X-ray however, nuclear medicine scans are far more superior concerning early detection.
- Provides detailed assessment of bone cortex, bone expansion, periosteal reaction, and / or subtle fractures.
- Evaluation for disc herniation or injury in communities where MRI is not available or when a patient is not a candidate for MRI evaluation.

## **Magnetic Resonance Imaging**

- Widely utilized for the differential diagnosis of both pathological and acute lesions.
- In recent times MRI has replaced CT as the gold standard in the evaluation of cervical, thoracic, and lumbar disc disease.
- No other imaging modality defines the anatomical relationship of the intervertebral disc and the content of the spinal canal as accurately as an MRI.
- Gadolinium enhanced MRI or a contrast MRI of the spine differentiates recurrent disc herniation from epidural scar tissue formation in post-operative patients.
- Unparalleled evaluation of spinal cord injury has been obtained with MRI.
- Only imaging modality which can visualize ligamentous tears, bone contusions, spinal hematomas, and spinal contusions.
- Can evaluate bone hemorrhage, bone marrow edema, and infection of soft tissue and bone.
- MRI provides the most sensitive imaging modality in the detection of osseous metastatic disease in the spine.
- Definitive diagnosis of multiple sclerosis. MRI is the first and only imaging modality that allows direct visualization of the central nervous system plaques that characterize MS. Recently, the use of contrast has made it possible to distinguish between acute inflammation and fresh plaques in areas of chronic involvement.
- Soft tissue injury to virtually every joint of the body.

## **Bone Scan Testing**

- Bone scanning is generally done after conventional X-rays have been performed. X-rays generally suffice to diagnose most skeletal abnormalities, however, they may fail to detect processes that have only subtly altered bone density or configuration such as early infection, early metastatic disease, or trauma insufficient to disrupt the bone cortex.
- Clinical indications include a patient with acute trauma and unresponsive, persistent, painful chief complaints when X-ray evaluation has been negative or equivocal.
- Patients with a history of metastatic disease and present complaints that are unresponsive.
- Detects the presence of increased bone metabolism secondary to fracture, infection, vascular



infarction, neoplasm, arthritides, and metabolic diseases, such as Paget's and fibrous dysplasia.

## Electrodiagnostic Testing

- Electrodiagnostic or electro-neurodiagnostic procedures are reliable studies which provide an objective measure of function in related sensory and motor nerves. They have been studied in large groups of normal subjects and in patients with a wide variety of neurological deficits. The usefulness of these studies is their ability to demonstrate abnormal neurologic system function when the history and/or physical examination are equivocal. They also help to define the anatomic distribution of a disease process and to monitor objective changes in a patient's status. The following electrodiagnostic tests were determined by the Guidelines for Chiropractic Quality Assurance and Practice Parameters to have a "type A-level 1" rating; electromyography (EMG), nerve conduction velocity testing (NCV), somatosensory/dermatomal evoked potentials (SEP/DSEP), H-Reflex and F-Waves.<sup>43</sup>

## Electromyography

- Electromyography studies the activity of the striated muscles using electronic techniques. Electrodes are placed over the belly of a muscle allowing for the study of the electrical activity of that muscle.
- Needle electromyography (EMG) is used to help detect a loss in neurons innervating a muscle. This may be the result of nerve root compression, disc herniation, foraminal encroachment and peripheral nerve injury. These conditions can lead to axonal degeneration. Like all electrodiagnostic testing, the EMG is an extension of the history and clinical exam and must be correlated with those findings. Essentially the EMG is a motor test that can help differentiate proximal and distal lesions as well as peripheral versus root dysfunction, myopathy and neuropathy.
- An abnormal EMG for radiculopathy will demonstrate fibrillation potentials and positive waves in a myotomal distribution with abnormal paraspinal findings and extremity abnormalities. In normal resting muscle, no electric activity is detected. During voluntary contractions the action potentials of motor units appear. In motor unit disorders, electric activity appears in resting muscle. In essence, the presence of fibrillation potentials in a root distribution with paraspinal findings is reliable evidence of radiculopathy. A muscle fiber that is not innervated undergoes spontaneous rhythmic contractions called fibrillations which are detected by EMG. There should be findings from two or more muscles receiving innervation from the same root, preferably by way of different peripheral nerves, with normal findings in an adjacent nerve root (i.e., in C7 radiculopathy, denervation should be seen in the triceps (C7/8) and pronator teres (C6/7), but not the extensor indices (C8/T1).)
- The text Mayo Clinic Examinations in Neurology suggest that the earliest evidence of nerve degeneration is failure of a nerve to respond to electric stimulation below the sight of injury. This usually occurs 3 to 4 days after the injury. The earliest significant EMG abnormalities can be detected 8 to 14 days after an injury (this is called *transient fibrillation potentials*). Spontaneous fibrillation does not occur until 2 to 4 weeks after the nerve has been damaged. In essence, an EMG test would not be medically necessary until 2 to 4 weeks post trauma.<sup>44</sup>

## Motor and Sensory Nerve Conduction Velocity

- A nerve conduction velocity (NCV) study helps diagnose nerve injuries and diseases

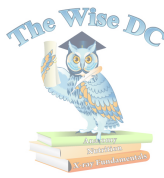
affecting the peripheral nervous system. A nerve conduction velocity study documents the extent that a nerve reacts (amplitude) how quickly the nerve responds (latency) and the speed the stimulation travels through the nerve (velocity). The NCV provides information about the motor unit. This is the physiologic entity consisting of a motor neuron and all the muscle fibers it innervates. It also evaluates peripheral sensory nerves. For example, a cervical study consists of testing the median and ulnar motor and sensory nerves and the radial sensory nerve. A lumbar study consists of testing the peroneal motor, tibial motor and the sural sensory nerves. The primary indication for the use of this procedure is persistent muscle weakness, soreness, fatigue, joint pain, neck pain, upper or lower back pain, pain in the extremities and numbness in the extremities. The procedure utilizes surface electrodes. Through this method the nerve is electrically, non-invasively, stimulated. The reaction of the nerve to stimulation is monitored by applying appropriate recording electrodes on the skin at standardized distances from the point of stimulation.

- NCV's are used to differentiate types of neuropathy. Wave forms, latencies and amplitudes are recorded. Sensory NCVs record the sensory nerve action potential (SNAP), when peripheral sensory nerves are stimulated. Motor NCVs record compound muscle action potentials (or CMAP) when peripheral motor nerves are stimulated.
- Motor conduction velocities and amplitudes are recorded and tabulated. Conduction velocities are measured by stimulation at two different points of the same nerve trunk. The velocity is calculated by  $D/T$ , where  $D$  = the distance between the two sights and  $T$  = the latency time between the two points. Typically the ulnar, median, tibial and peroneal nerves are studied in both sensory and motor NCV exams. NCVs are clinically appropriate tests to differentially diagnosis carpal tunnel syndrome, tarsal tunnel syndrome, ulnar neuropathies, peroneal neuropathies, radicular neuropathy, polyneuropathy and plexopathy. Amplitude abnormalities are suggestive of axonal loss while conduction abnormalities are suggestive of focal demyelination.<sup>45</sup>
- NCVs are usually normal in radiculopathy because the lesions are proximal to the dorsal root ganglion. However, with axonal degeneration of the roots, compound muscle action potential amplitudes may be reduced within 7 days post-injury. NCVs may be performed, if medically indicated after one week post-injury or trauma.<sup>46</sup>

### **Somatosensory / Dermotomal Evoked Potentials**

- SEP/SSEP/DSEP is a method for testing the integrity of the somatosensory pathways. It is used to test large sensory fiber tracts of the peripheral nervous system (nerve and root) and their pathway into the spinal cord through and into the somatosensory cortex. The SEP allows access to functional evaluation in sensory roots that otherwise cannot be measured. In essence, the procedure helps localize functional segmental abnormalities.

The major clinical application of SEP/SSEP/DSEP is in the detection of physiologic impairment, through proximal parts of peripheral nerves, spinal nerve roots, the spinal cord and the brain stem. SEPs help localize the anatomic sight of sensory pathway lesions and can identify impaired conduction from axonal loss (reduced amplitude of response) and/or demyelination (prolonged or absence cortical wave forms).



# Chiropractic Treatment Methodologies

## Initial Care

1. Protection and support: In the first several hours following tissue injury, there is effusion in the soft tissues and around the joints. This develops rapidly into an inflammatory response, with tissue congestion. At this initial stage, activity restrictions and protection of the injured area are necessary to prevent further damage. This may require the use of a soft cervical collar for one or two days. The continued use of complete rest and a collar for more than one or two weeks has been shown to be counterproductive as this type of management slows the body's healing response. It is important to keep the patient active, but without causing further injury or aggravation of symptoms.
2. A cervical pillow designed to support the normal curve of the cervical spine can be utilized throughout the course of care. This procedure will help regain cervical alignment and induce muscular relaxation.
3. Cryotherapy: Frequent and regular cooling of the inflamed tissues controls inflammation and swelling and provides pain relief. A cold pack should be placed over the injured tissues approximately 10-15 minutes per hour. This can also be continued beyond the initial, acute phase to provide localized cooling after each exercise session, which increases the circulation response.
4. Gentle manipulative techniques to keep the region of the injury mobile thereby enhancing the healing process and limiting joint fixations.

## Active Strengthening and Movement

Strengthening can help return the injured neck to full function. Numerous studies using various exercise approaches have described the benefits of the active approach. Simple standard stretching exercises, whether at home or in the clinic, demonstrate little or questionable therapeutic value. Dynamic exercise, using progressive resistance to stimulate the muscles and nerves, is the most useful form of active exercise.” A rational approach gives consideration to the following:

1. postural control and balance of opposing soft tissues;
2. range of active motion of the injured spinal regions;
3. strength of the related musculature;
4. general muscular power (for daily activities); and
5. general aerobic fitness and endurance.<sup>47</sup>

## Rehabilitation Exercise Fundamentals

The introduction of rehabilitative exercises is dependent upon the patients tolerance and should be monitored closely for adverse responses.

**Principle of Use**--the human body has the ability to adapt to use and imposed demands thereby increasing the capacity and efficiency of the bodies various systems.

**Principle of Disuse**--dictates that your level of fitness will decline if you stop exercising.

**Overload Principle**-- in order for your cells to increase in size (hypertrophy) the workload must be increased beyond what the cells normally experience. This is referred to as overloading. Your body systems must be stressed beyond normal levels of activity if they are to improve. The overload is a positive stressor and is the basis of stress adaptation.



The components of overloading include exercise intensity or load, exercise duration, exercise frequency, and exercise repetitions. Each of these components can be increased to impose an overload. **Exercise intensity** or load is probably the most important component of the overload principle. For strength gains to occur, your load should represent an intensity, which is at least 60% to 80% of your muscle's maximum strength. This will usually allow the performance of seven to ten repetitions of a particular exercise before resting. Practically speaking, the amount of resistance you use in an exercise is determined by trial and error. In designing an exercise program, always underestimate an individual's lifting capabilities.

Increasing the length of the exercise period (**exercise duration**) can impose an overload. It is not uncommon for body builders to perform various exercises, in excess of eight hours per day, prior to a competition.

**Exercise frequency** refers to the number of days per week that an individual exercises. To improve or maintain muscular strength or endurance, the average individual would need to exercise on alternate days or approximately three to four days per week. Generally, each major muscle group should be overloaded every 36 to 48 hours. Conversely, elite athletes preparing for competition may require daily training sessions.

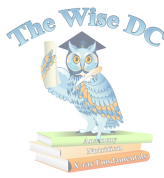
**Exercise repetition** is one complete movement of an exercise. A series of repetitions, performed consecutively, is referred to as an exercise set. Exercise repetitions will determine the type of adaptation. For example, an increased weight load with low exercise repetitions will result in muscle hypertrophy. A decreased weight load with high exercise repetitions is best for achieving muscle endurance.

**Rest** is the amount of time between the performance of an exercise set. The amount of rest required will depend upon the load demand. The greater the load, the greater the fatigue, and therefore, a greater rest period is necessary for recovery. The amount of rest is also dependent upon the type of adaptation that is desired. For endurance (oxidative) adaptations to occur, you will normally rest less and exercise at a lower intensity than when you are attempting to develop strength. To develop muscle endurance, rest 30 seconds between sets. High intensity strength training, such as squat activities, may necessitate rest periods of up to 5 minutes between sets. The rest period for most exercise programs is approximately one to two minutes between sets.

**Principle of Progression**--often referred to as progressive overload or progressive resistance exercise. As exercise adaptations occur over time, your body experiences a sensation of reduced effort for a given performance. This is due to the physiological adaptations enhancing the body's ability to create energy and remove metabolic waste products. To achieve steady improvement, training intensity should be continually increased. However, it is important to progress slowly, as too rapid a progression may lead to overuse injuries.

**Principle of Specificity**--indicates that you must train a specific energy system (often referred to as metabolic specificity) or specific muscle groups (known as neuromuscular specificity) in order for them to improve.





**The Principle of Warm--Up and Warm--Down--** a properly designed exercise program will include a warm--up (low level activities, such as stretching and slow walking, performed prior to more strenuous exercise), a stimulus period (the performance of strenuous exercise) and a warm--down period, also known as the cool--down (performed immediately after the stimulus period). The warm--up and warm--down help to prevent muscle soreness and injury and prevent excessive strain on the heart. For example, if you stop running abruptly, blood may pool in the legs, thereby decreasing the bloods return to the heart.

**The Principle of Recuperation--**due to the stress placed on the body by exercise, rest and recuperation are essential. Inadequate recuperation can result in over training syndrome and overuse injuries such as epicondylitis. However, extended periods of rest may lead to deterioration in one's fitness level.

**The Principle of Reversibility--** the benefits of training are transient and dependent upon continued exercise. You must continue to exercise to avoid deconditioning (use it or lose it). It is said that for every day of inactivity, it takes two days of exercise to return to one's normal fitness level.

## **Myofascial Trigger Point Therapy**

A whiplash trauma can cause repetitive muscle strain and prolonged muscle hypertonicity which can manifest itself in the form of trigger points. Trigger Points can cause the development of a reflex arc within the spinal cord. Nociceptive afferent bombardment of the spinal cord from Trigger Points can cause interference with the nervous system. The spinal cord will then send efferent impulses back to the hypertonic muscle sustaining the muscle in that condition. This reflex arc results in increased neural activity disrupting the nervous system. Trigger points can also be caused by gross trauma, visceral disease, arthritic joints or emotional stress.

## **Characteristics of Trigger Points**

"An active trigger point is always tender, prevents full lengthening of the muscle, weakens the muscle, usually refers pain on direct compression, mediates a local twitch response of muscle fibers when adequately stimulated and often produces specific referred autonomic phenomena, generally in its pain reference zone."<sup>48</sup>

## **Trigger Point Histology**

"The trigger point nodule itself is thought to be a region of localized muscular contracture, in which a subset of muscle fibers are locked by failure of the actin/ myosin heads to release."<sup>49</sup>

## **Common Methods to Treat Trigger Points**

- Ischemic compression - sustained pressure to a trigger point for approximately five seconds to a minute utilizing the thumb for smaller muscles, the elbow for larger muscles or a T-bar instrument. Ischemic compression pressure is increased as the sensitivity of the trigger point decreases. Pressure is applied until the trigger point is no longer tender.
- Acupuncture.
- Moist heat packs.



- Ultrasound.
- Spray and stretch.
- Injection of lidocaine or prednisone.

## **Therapeutic Modalities Commonly Used in the Treatment of Whiplash Injury**

- Ultrasound: uses sound waves and may be used to decrease scar tissue, increase blood flow, or decrease pain.
- Interferential Current: uses electrical current to decrease pain, can also be used to elicit muscle contraction and decrease swelling.
- Acupuncture: uses small, solid needles to encourage healing, reduce pain, and improve function of affected areas of the body.
- Rest: by decreasing your activity you allow your body a chance to heal itself. When you start to feel better it is important to ease back into activities which might be aggravating. Listen to your body - pain means that you have done too much.
- Ice: ice decreases the metabolism of your cells so that they do not die despite a decrease in oxygen to the injured area. Ice should be kept on for approximately 15 minutes, several times a day. The injured area should be elevated (above the level of your heart) at the same time. Use a wet towel between the ice and your skin to protect against frostbite. You can use frozen vegetables, cold packs, or real ice.<sup>50</sup>

## **Whiplash Update: New Research About Chiropractic Utilization in America**

With respect to all automobile claimants for all providers seen, regardless of specialty:

- 53% of all claimants have X-rays taken during their claim.
- 15% of claimants have an MRI performed.
- 7% of claimants have a CT scan performed.
- 4% of claimants have an EMG performed.
- 1% of claimants have muscle strength testing.
- 66% of all claims involve cervical strains/sprains.
- 56% of all claims involve back strains/strains.
- 10% of all claims involve shoulder injuries.

When looking at data specific to the chiropractic profession:

- 33% of all claimants will see chiropractors.
- 41% of claimants with strain/ sprain-only injuries will see chiropractors.
- The average chiropractor sees a claimant for 26 visits, on average.
- The average charge per visit is \$130 to \$167.
- The average total chiropractic charge for providing treatment for a motor vehicle accident is \$2,509 to \$3,239.<sup>51</sup>

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