The Occurrence of Injuries in Sports and the Workplace

An Interactive Qualifying Project Report

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Abstract

This report explores the various injuries sustained in sports and the workplace. We begin by examining injuries in the broad sense, in order to understand different types of injuries and their likely causes. The physiology of muscle, ligament, tendon, and bone with respect to injuries are examined. Three common injuries to the knee, back, and hand are reported as the most frequent injuries in sports and the workplace. The anatomy of the knee, back, and hand are all examined to develop a further understanding of the topic at hand. With knowledge of the physical characteristics of the human body, which contribute to knee, back and hand injuries, we can focus on three mainstream extreme sports: rock climbing, mountain biking, and alpine skiing. The actions in each of these sports and their impact of knee, back, and hand injuries are examined. Minimizing such injuries in these extreme sports by preventative measures is documented. The workplace can produce just as serious injuries to the knee, back, and hand. Recent studies have shown an increase in the number of injuries in both sports and in the workplace. Conclusively, the increasing trend in extreme sports and physical labor in the workplace has brought about a large string of injuries and their occurrences, as well as a market for protective devices to hinder injuries.

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Acknowledgments

We would like to sincerely thank the help, effort, and uplifting spirit of Mustapha Fofana PhD. Without his dedication to this project and the field, the following work would have been impossible to achieve.

CHAPTER I: The Occurrence of Injuries in Sports and the Workplace

Introduction

Sports are more than just games or pastimes. They provide individuals an opportunity to an adventurous side of themselves, which otherwise may be lost due to the routine crush of work. Sports are a major part of our society. They are seen as both healthy and fun activities. Nearly half of the American populations are involved in frequent exercise. Whether they are exercising in a gymnasium, participating in organized sports, or are simply outdoor enthusiasts, all of them are gaining from the advantages of sport and exercise bring. There are, of course, physical benefits that come with any sport. Those who concentrate on staying in the gymnasium can tailor their physical gains by changing particular exercises, perhaps to benefit their cardiovascular fitness or just brut strength. Athletes who challenge themselves in their sport often find it beneficial throughout their everyday life as well. Sports can boost a person's self-esteem, confidence, and self-control.

As there are many individuals who enjoy the leisure of sports, there are even more who enjoy the pleasure of working longer and harder. The workplace setting may differ from occupation to occupation. While the most physical activity the work office setting may have is the tireless task of pecking at a keyboard and dropping the weight of their finger to click the mouse another setting may require the use of muscles to perform the job. An industrial or warehouse setting may entail an employer to physically move thousands of pounds of material within a day. Whatever the setting, injury to the body is always an imminent threat.

With the growth of competitive sports, athletes are constantly pushing their bodies' limits, often exceeding their threshold. The injuries that follow can range from a temporary to a permanent injury, or can even result in death. The most severe injuries in sports occur when people are moving at high speeds. Certain sports require speed and demand deliberate and delicate moves. People don't usually experience traumatic injuries unless a high velocity is involved, although this is not always the case, such as in ACL injuries. The three most common sports that have the most injuries, due to high velocities, are mountain biking, skiing, and rock climbing. Much advancement has been made in the medical field to begin compensating for serious injuries that may occur while exercising. Medical experts are not the only ones who need to be educated in these areas. Engineers also need to gain knowledge to be able to make new advances to prevent such injuries. The creation of replacement body parts with the use of many new materials has been added to the medical field through the efforts of engineers. Biomedical and mechanical engineers work in conjunction to make knee, ankle, and elbow braces that can drastically reduce injury and healing time. They have also worked their way into the sports themselves, by designing appropriate equipment that minimizes severe injuries.

The objective of this report is to characterize injuries in sports and the workplace. We discuss sports and injuries in general to give a clear background of the classification of injuries. We identify injuries that occur most commonly in three sports with high velocities and jobs in the workplace that induce injury. For each sport we look into what forms of protection exist to prevent these injuries, and under what specifications they are designed. Similarly, we also explore what safety precautions are taken in the workplace in order to prevent injuries.

The remainder of the report is characterized as follows. Chapter II discusses the anatomy which is potentially affected by common sports and workplace injuries. Chapter III characterizes injuries that likely occur in sports and the workplace. Chapter IV discusses these three injuries with respect to cycling, rock climbing, and skiing. Chapter V is the overall discussion of our investigation. The conclusion is formed in Chapter VI

CHAPTER II: Epidemiology of Knee, Hand, and Back

2 Introduction

In the three sports within our scope, there seems to be a trend in overuse injuries specific to the knee, hand, and back. Knee and back injuries can be seen in any of the three sports, whereas hand injuries are seen much more frequently in rock climbing than in any other sport although they still do exist. Knowing the anatomy of each of these pertinent areas can help us understand why the injuries do occur and possible methods of prevention.

2.1 Anatomy of the Knee

It is crucial to understand the anatomy of the knee before understanding why any injury may occur. The knee gives us the versatility of our mobility. In conjunction with the hip joint and rest of the leg, we are able to propel ourselves in a variety of motions. The knee also allows for shock resistance without crippling our legs or hip joint. It is obvious that the list goes on of the applications and advantages of the knee joint. However, what is not so obvious is how the joint actually functions.

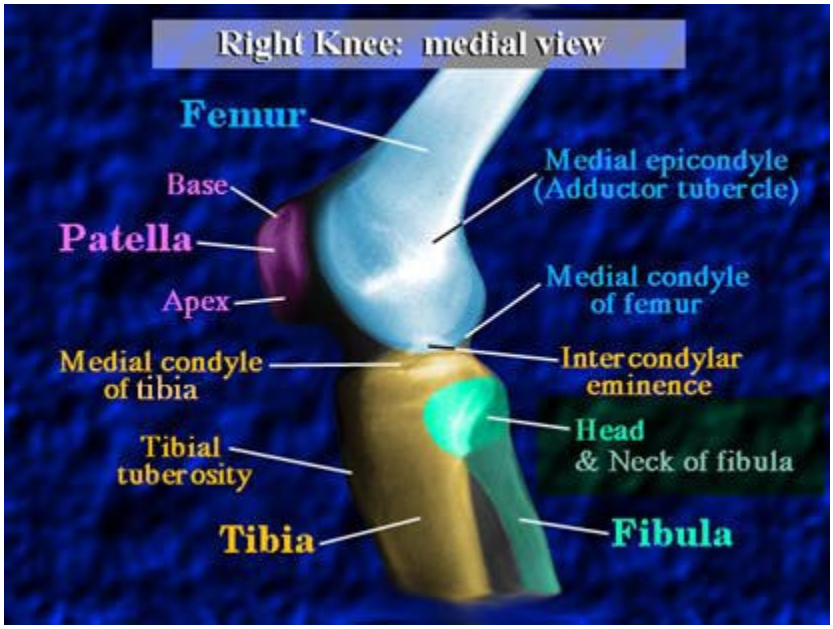

Figure 1: Anatomy of the Knee [1]

The knee joint is primarily made up of the femur and the tibia (See Figure 1), while the fibula is attached slightly lower than the joint on the lateral side of the tibia. The patella protects the anterior of joint by gliding on the lateral and medial condyle of the femur. Ligaments and cartilage lie in the joint to prevent movement out of range and protection of the bones. The four major ligaments are the two collateral ligaments, the fibular (lateral) and tibial (medial), and the two cruciates, the anterior and posterior. The main cartilages in the knee are the lateral and medial meniscuses.

The two collateral movements restrict movement out of the joint's range of motion in a side to side manner. The fibular collateral ligament is attached between the side of the lateral femoral condyle and the head of the fibula. This tightens as the knee is extended which slightly helps to prevent overextension. The tibial collateral ligament extends between the sides of the medial femoral and tibial condyles. This joint does

[1] Huston, Craig, B.S.E., Brandser, Eric, M.D. "Right Knee: Medial View." Pg. 1

more to protect hyperextension as it is reinforced by the oblique popliteal ligament which is a thickening of the posterior part of the capsule.

The cruciate ligaments are located in the center of the joint. They rise upward from the central nonarticular portion of the tibia and cross as they rise to connect between the condyles of the femur. The anterior cruciate ligament originates anterior of the intercondylar eminence of the tibia. It then rises upward and backward to the inner surface of the lateral femoral condyle. This prevents anterior displacement of the tibia, also known as "forward drawer" in many ACL studies. The posterior cruciate ligament originates posterior to the intercondylar eminence of the tibia. It rises upward and forward on the medial side of the ACL to connect internal to the medial femoral condyle. The posterior cruciate ligament prevents posterior displacement of the tibia. Since the two cruciate ligaments cross each other their fiber in tension may help to prevent side to side movement along with the collateral ligaments. [2]

Placed at the medial and lateral tibial condyles are wedge shaped crescent rims of fibrocartilage known as the medial and lateral meniscuses. They rise higher on the medial and lateral sides, known as the "rims" to deepen the joint for the medial and lateral femoral condyles to rest in. The two ligaments begin and end with what is know as a "horn" at the respective position of the intercondyle eminence of the femur. Not only is the medial meniscus attached at both horns, but the rim is also attached to the tibial collateral ligament. The medial meniscus is oval shaped also to complement the shape of the medial femoral condyle. The lateral meniscus is weakly attached at the horn and much less so to the fibular collateral ligament. The lateral meniscus is circular shaped with respect to the medial meniscus to accommodate the shape of the lateral

[2] "Atlas of Anatomy." Pg. 66-72

condyle. As the femoral condyles rotate in the knee, the medial and more so the lateral meniscuses slightly move to avoid the crushing force of articulation. [3]

2.2 Anatomy of the Hand

Similar to the knee, the hand has a variety of functions. The hand plays a large role in all sports and in the workplace. In any workplace setting it plays a large role, whether it is typing or lifting, while in sports it is used in virtually every interaction. Its complex makeup is part of the reason why it can do so many things. Within the wrist and hand there are 27 bones, these can be seen in Figure 2, which in conjunction with each other allow a multitude of movements.

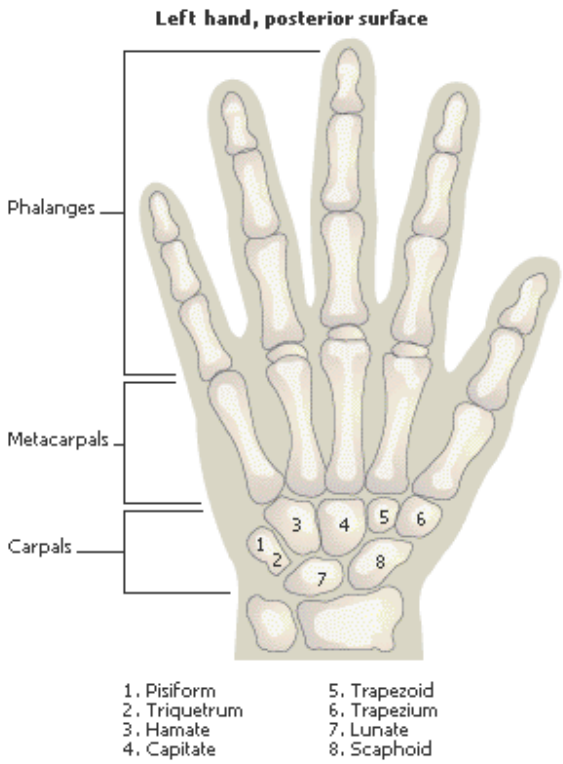

Figure 2: Anatomy of the Hand[4]

[3] "Atlas of Anatomy." Pg. 68 & 69

The bones of the hand and wrist will allow movement in a variety of positions in order to bring the hand in proximity with the point of action. The wrist is able to move the hand in four ways due to the orientation of the bones in the wrist. The wrist is able to be in flexion, which is when the hand is bent toward the anterior aspect of the forearm in an anatomical position. The opposite is also possible and known as extension, when the hand is bent toward the posterior aspect of the forearm. The hand can also adduct or abduct, or rotate medially or laterally, respectively. These motions are also accentuated by pronation and supination , but are made possible by the construction of the forearm.

The construction of the wrist allows the hand to move in a variety of ways, and with a brief description it can easily be seen why. There are two rows of four bones that make up the wrist. The proximinal row is located closest to the radius and the ulna. The distal row is in between the proximinal row and the carpals.

In the anatomical position, the lateral most bone in the proximinal row is the scaphoid, also known as the navicular. It is closest to the thumb and named for its boat-like shape. Next, medially, is the lunate, named for its semi-lunar appearance. Adjacent to the lunate lies the triangular, or the triquetral, whose naming origin is quite geometrically obvious. The medial most bone in the proximinal row which lies anterior to the triangular is the pisiform. The pisiform is the smallest bone in the wrist and resembles the shape of a pea. With these four bones aligned, their proximinal edge acts as a surface for a joint with the radius and the ulna. Their distal edge creates a concavity which allows the distal row to fit closely into it.

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[4] "Bones of the Hand." Pg.1

The distal row also contains four bones. The trapezium lays lateral most, which was also known as the greater multangular bone due to its large irregular shape. The trapezium fits between the trapezoid and the scaphoid and a beaklike ridge just forward toward the carpals. The trapezoid, formerly known as the lesser multangular bone, lies medially and slightly posterior to the trapezium. Its medial side lies against the lateral side of the capitate. The capitate extends proximinally to fill the highest point of the convex arch in the first row. Lying medially to the capitate is the hamate, which never quite reaches the medial side of the wrist. The triangular and pisiform seem to cover this medial surface. [5]

The concavities formed by the bones of the wrist create four forward projections, two on each side. There is one on the lateral end of the scaphoid, and another on the beaklike protrusion on the trapezium. On the medial side there is one on the pisiform, which projects forward from the triangular. There is also another on the hook of the hamate. A fibrous band called the flexor retinaculum, stretches across the anterior of the hand and connects these four projections to ensure the trough like concavity of the carpus. The flexor reticinaculum also acts as a fibrous roof to hold down flexor tendons of the fingers on their way across the wrist. [6]

[5] "Atlas of Anatomy." Pg. 68 & 69
[6] "Atlas of Anatomy." Pg. 68 & 69

2.3 Anatomy of the Back

The back is the framework of the entire body. Its 24 vertebrae allow our upper body to move in a number of ways (See Figure3). Its curvature also supports the structural integrity of our posture. In the workplace the back can see a number of perils, along with in sports. Without proper care during these activities, many eventually damage the workings of this ever important feature of our bodies.

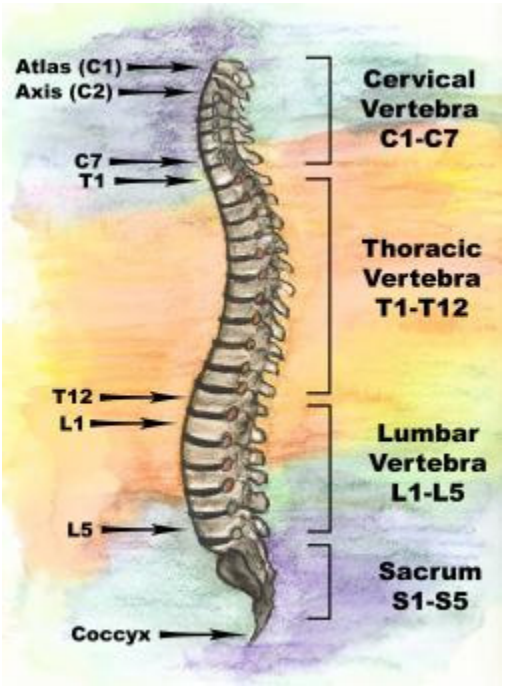


Figure 3: Anatomy of the Back[7]

The back is made up of 24 bones arranged atop of one another called vertebrae. Together they create a flexible yet resilient column between the back of the skull and the top of the pelvis. This column allows the trunk of the body to rotate more freely and still

[7] "Anatomy of the Back." Pg. 1

provide protection for the spinal cord to run through it. Throughout the spine there are four opposing curves, each having differently shaped bones and functions. The curvatures are dubbed: cervical, thoracic, lumbar, and sacral. Beneath the sacral curvature lies a fused bone called the coccyx, i.e. tail bone.

Each vertabra is made up of two main parts. The vertebral body bears most of the weight, and the neural arch, forms part of the vertebral canal housing the spinal cord. The vertebral arch has two processes which allow each vertabra to articulate with one another. The inferior process of the upper vertabra rests upon the superior process on the lower vertabra. Posterior to the vertebral arch lies the neural arch which also contains two processes. These, however, are a pair of transverse processes to which muscles attach. In the thoracic region, these processes articulate with the ribs.

Between each vertebra lies an intervertebral disc. These discs act as a shock absorber and prevent wear of the vertebral body. The discs are able to hold the spine directly upright; however these discs use the help of ligaments to stretch the anterior and posterior side of the spine. When the discs are in tension and compression the anterior and posterior longitudinal ligaments strengthen the back in bending.

The cervical curvature of the spine is made up of seven cervical vertebrae. The pronounced curvature develops around three to six months of age, when an infant must support the weight of his/her head in and erect position. The cervical vertebrae are relatively smaller than the thoracic and lumbar due to the fact that they do no support as much weight. The seventh cervical vertebrae, C7, can be seen when the neck is bent forward as it forms a bump at the meeting of the neck and back.

The thoracic curvature is made up of twelve thoracic vertebrae. The thoracic vertebrae are larger than the cervical and are shaped differently to accommodate the ribs. The transverse process is more of a facet than a process where it must articulate the ribs rather than constrict their movement. The curvature in this region originates while the child is in fetal development where it is the same curvature as the fetal position.

The lumbar region is made up of five, rather larger, lumbar vertebrae. The vertebral body is considerably larger than all other vertebrae due to the large amount of weight it supports. The curvature in the lumbar region develops around the one year mark of a child to accommodate the stresses associated with walking.

The coccyx and sacral region are made up of four and five bones, respectively. These bones are fused. The sacrum is the main attachment for the anterior and posterior longitudinal ligaments. The sacral hiatus allows for spinal injections to enter the spinal cord directly at the bottom of the sacrum. The coccyx serves as an anchor for the pelvis floor.

CHAPTER III: Characterization of Injuries in Sports

3 Introduction

Overuse injuries are the most common injuries that occur in sports. Overuse injuries are a result of wear and tear of the body, mainly occurring at the joints. Muscle pulls, neck pain, shoulder impingement, lower back strain, and runner's knee are some of the most common overuse injuries in sports.

3.1 Muscle Pull

The most common sports injury is a muscle pull. It is the most common because it can occur anywhere in the body. It is when a sudden force applied on the muscle can stretch it beyond its ability. You can pull a muscle from overuse, fatigue, or by a fall. It doesn't matter if you warm up, cool down, or stretch. These can only help reduce the incidence of the injury. To try to prevent a muscle pull you should work your muscles on a regular basis. [8]

When you pull a muscle you need to have rest until the pain goes away. Ice should be used to minimize the swelling. Ice should only be used for 20 minute intervals. When you are comfortable with the pain, you should begin stretching again. This slowly re-lengthens the muscle fibers. If you do not do this, the muscle will get pulled again.

[8] "Top 10 Sports Injuries." Pg. 1

3.2 Neck Pain

Pulled muscles in the neck or spasms can occur if a person looks up to fast. This usually happens when a tennis player quickly moves their head upward to hit a serve. The pain you experience is on one sight of the neck (See Figure 4), and you may feel your head pulled in that direction. Cyclist often experience neck pain due to the position of handlebars they use for racing. This is because they have their back bent low over the handlebars and have to cock their neck up to see ahead of them.

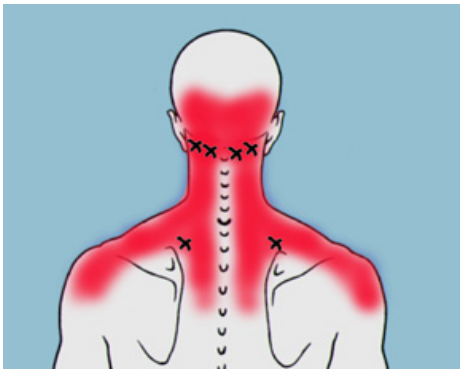


Figure 4: Location of Neck Pain[9]

When an athlete experiences neck pain they should apply ice in 20 minute intervals and stretch often. There are specific neck stretches that should be used such as, sitting in a chair and holding on to the seat and bending your head to the opposite side of the pain, and also to move your head in semi circles. These stretches can also be used to strengthen your neck to prevent an injury.

[9] "Neck Pain" Pg. 1

3.3 Shoulder Impingement

The bones in your shoulder are held together by the supraspinatus, infraspinatus, subscapularis, and teres minor muscles. These are known as the rotator cuff muscles (See Figure 5). Any weakness in the muscles can make it hard for the shoulder to properly move about in the joint.

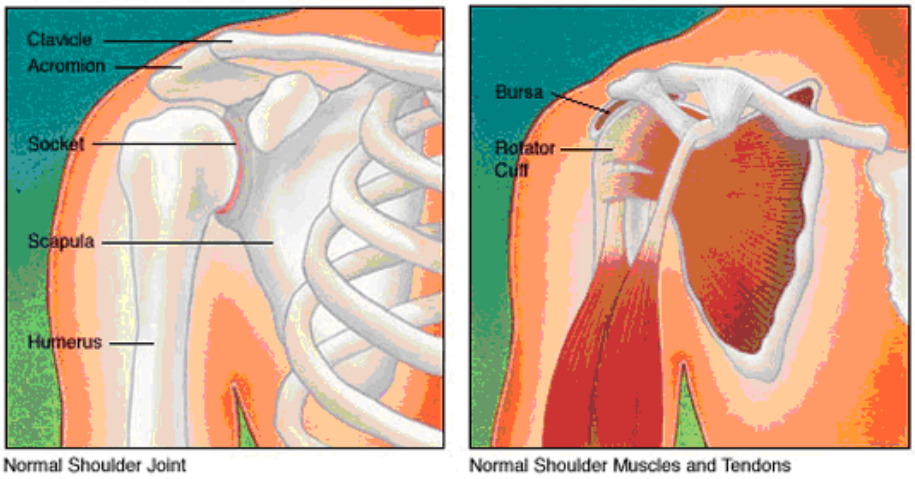


Figure 5: Anatomy of the Shoulder

When the shoulder is continuously used in the overhead position, such as in softball, tennis, volleyball, swimming, and weight training, the rotator cuff stretches out. The joint then becomes loose in the socket. If the shoulder is loose, and you extend your arm backwards, the head can slide forward and catch the tendon and biceps between the ball and the socket. The impingement makes the tendons inflamed (See Figure 6). [10]

Anti-inflammatory drugs are normally used to treat shoulder impingement. Once they wear off however, the problem will still persist and the tendon can become impinged again. Range-of-motion exercises can be used to help strengthen the rotator cuff

[10] "Top 10 Sports Injuries." Pg. 1

muscles. Physical therapy, ultrasounds, heat, and electrical muscle stimulation is also used.

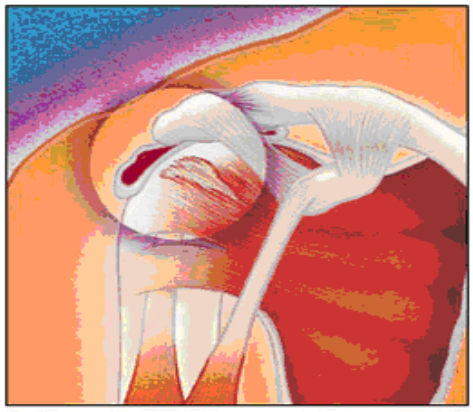


Figure 6: Impingement Lesion of the Shoulder[11]

3.4 Lower Back Strain

Lower back strain can be caused from moving awkwardly, lifting something heavy, twisting differently, or doing an unpracticed activity. Lower back injuries are a result of weak or tense muscles, or muscle strain. If you overload your muscles when they are not used to it, it can cause them to pull or tear the muscle fibers. This can cause the muscles to spasm and cause extreme pain. Weightlifters, golfers, martial art athletes, and tennis players are the most common sports that experience back injuries because of their unilateral motions.

The extreme pain of back spasms can disable a person. Rest and anti-inflammatory medicine is essential. Ice should be placed on the back for 20 minute intervals. Physical therapy is a necessity if the pain doesn't go away within 2 weeks. This should include ice, heat, electrical stimulation of muscles, stretching, and deep-tissue massaging.

[11] "Shoulder Impingement." Pg. 1

Exercises to strengthen the back and abdominal muscles should be used to help against future back pain.

3.5 Runner's Knee

Runner's Knee, or chondromalacia patella, is the most common cause of knee pain. This is caused when there is a misalignment of the kneecap in its groove. When the kneecap functions normally, it goes up and down in the groove as you flex and straighten your leg. When a person has runner's knee, the misaligned kneecap pulls off to one side and rubs on the side of the groove. This causes the cartilage on the side of the groove and in the back of the kneecap to wear out. This can cause a buildup of fluid and swelling of the knee. [12]

To treat a person who suffers from runner's knee, the quadriceps muscle must be strengthened. This is the muscle that hooks into the kneecap and helps align it in the groove. Isometric exercises are recommended to strengthen the quadriceps. Full leg extensions should not be used because it can cause the kneecap to rub more on the bone and worsen the condition. Soft tissue massaging should be used to work the quadriceps, this helps stretch the muscle fibers and alleviates the muscle contraction. Aspirin should also be taken to reduce inflammation within the cartilage of the kneecap.

[12] "Top 10 Sports Injuries." Pg. 1

CHAPTER IV: Extreme Sports and their Underlying Injuries

4 Introduction to Cycling

Over the past few years, the popularity of cycling has grown. Not only is it popular among young children, but also with adults. The popularity of professional cycling has grown since the accomplishments of Lance Armstrong, BMX (Bicycling Motocross Racing), and on- road racing. Mountain biking has also become an increasingly popular competitive and recreational sports among a wide range of age groups. This growth has fueled the bicycle industry. Mountain bikes account for more than half of the US bike sales owned by at least 25 million Americans. New technological innovations and designs flood the market every year. The first Olympic mountain bike race was in the 1996 summer games, and now over 85,000 Americans participate in these types of organized races. [13]

[13] "High Velocity Injuries." University of Utah School of Medicine. Pg.1

Figure 7: Cycling Race[14]

The mountain bike is far more evolved than that of a road bicycle. There are many more advances in the construction of the bike including wide knobby tires that have lower inflation pressure, superior braking systems, and shock-absorbing suspensions that make mountain bikes suitable for off-road riding. One popular form of competition is a cross-country race. It is a 2-3 hour race that a large number of cyclists participate in. These riders must maneuver an uphill and downhill course, where speeds may be higher than 50 miles per hour. One event includes a short downhill that has a series of jumps and gates. Cycling is a wonderful form of exercise, but whether cycling is a form of competition or simply for a recreational rider, the rough, varied terrain requires supreme bike-handling skills and puts the rider at a risk of injury. Awareness of these injuries can help healthcare professionals manage the traumatic and overuse injuries that mountain bikers experience.

[14] Fevžer, Aleš. "Cycling Races." Pg. 1

4.1.1 Cycling Injuries

In recent studies it is found that more than 80% of approximately 650 mountain bikers who participated in the surveys were injured in off-road crashes during a 1 year period. Many of these injuries were small, but 20% were reported to be a traumatic injury which acquired medical attention and even limited the rider's ability to ride. Minor injuries are injuries such as abrasions, contusions, and lacerations. Concussions and fractures are less common. The fractures usually occur to the upper extremities and involve the fingers, wrist, radial head, and metacarpals. Shoulder dislocations can commonly occur during falls as a cyclists arm is raised. Serious injuries, such as pelvic fractures, intra-abdominal injuries, facial fractures, and severe brain injuries have also been some examples of cycling injuries and are summarized in Table 1. [15]

[15] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

Table 1: Injuries Sustained by Cyclists (By Type, Etiology, and the location of injuries) [16]

Type	Etiology	Injuries
Overuse	Neck and back	Cervical strains, lower back pain
	Handlebar neuropathies	Ulnar nerve (deep palmar branch), median nerve
	Saddle	Skin chafing, ulceration, irritation (saddle sores), ischial tuberosity pain, fibromas, pudendal neuropathies, impotence, urethral trauma (urethritis, hematuria), vulval trauma
	Hip	Trochanteric bursitis, iliopsoas tendonitis
	Knee	Patellofemoral syndrome
	Foot/ankle	Metatarsalgia, plantar fasciitis, Achilles tendonitis, paresthesias
Traumatic	Head	Skull fracture, concussion, brain contusion, intracranial hemorrhage
	Face/eye	Contusions, facial fractures, dental fractures, corneal foreign bodies
	Musculoskeletal	Fractures, dislocation, strains
	Chest	Rib fractures, parenchymal lung injury
	Abdomen	Splenic rupture, hepatic laceration, renal contusion, pancreatic trauma, vascular perforation, small or large bowel contusion, rupture, traumatic hernia
	Genitourinary	Urethral and vulval trauma, rectal trauma, pelvic fractures
	Skin and soft tissue	Abrasions ("road rash"), lacerations, contusions

[16] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

4.1.2 Overuse and Traumatic Injuries

Overuse injuries are caused by interactions between a cyclist's body, the bike, and the terrain. Effects of small errors in the alignment of the bike and rider, as shown in Table 2, are magnified by the amount of hours of cycling and by repetitive lower extremity motions. Upper-body overuse problems can be caused by weight on the handlebars and the vibrations cased from riding on rough terrain. Riders who push beyond their own limits can also suffer from overuse injuries. Inadequate conditioning, sudden increase in mileage, hill climbing, riding intensity, and riding in too high of a gear, are factors that play a role as well.

Table 2: Determining the Correct Fit of a Bicycle[17]

Bicycle component	Key measurements	Adjustments
Frame size	Clearance between frame and crotch	While standing astride the frame of the bicycle: 1 to 2 inches for sports/touring bicycles, 3 to 6 inches for mountain bicycles
Saddle	Height	25 to 30 degrees of knee flexion of the extended leg when the pedal is at 6 o'clock position *or* Measure the inseam (wearing cycling shoes) from floor to crotch, and multiply by 1.09. *or* Maximum height whereby the rider is not rocking back and forth across the seat when riding. Generally lower in mountain bikes to maintain stability and maneuverability
	Fore/aft position	With pedals at 3 and 9 o'clock position, the front of the patella should be directly in line with the front of the crank arm.
	Tilt angle	Set level (use carpenter's level), or with slightly elevated front end.
Upper body	Handlebar height	At least 1 to 2 inches below top of the saddle (up to 4 inches for tall cyclists)
	Reach/extension	When elbow is placed on the tip of saddle, the extended fingers should reach the transverse part of handlebars.
	Width of bars	At shoulder distance, wider in mountain bicycles
Foot	Position on pedal	Foot should be in neutral position, toes not pointing up or down. Ball of foot should sit over pedal axis.

[17] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

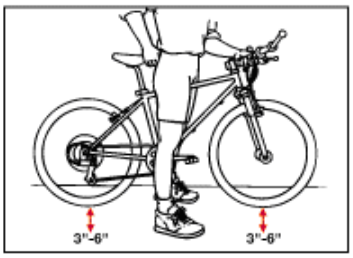


Figure 8: Positioning to determine the correct frame of a bicycle

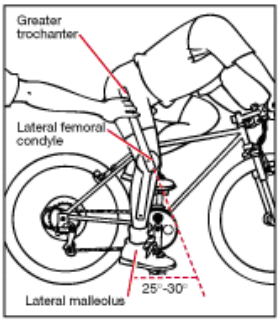


Figure 9: How to determine correct saddle height of a bicycle

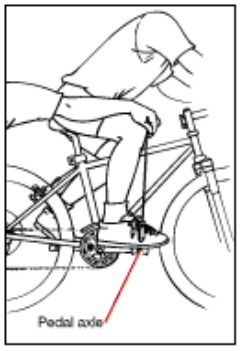


Figure 10: Correct Saddle Position [18]

To prevent overuse injuries, riders should be encouraged to begin with a basic level of training. They should gradually increase their mileage, hill climbing, gears, and intensity. Riders who are injured may have to alter their normal routine until the symptoms subside. A physical examination should look for anatomic variations that could potentially correspond with the mechanics of the bicycle.

[18] Kronisch, Robert L MD. "How to Fit a Mountain Bike."Pg.1

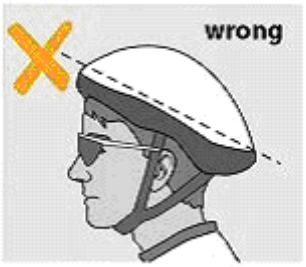
There are many factors that contribute to traumatic injuries. Mountain bikers associate their injuries from crashes due to excessive speed, unfamiliar terrain, inattentiveness, and riding above one's own ability. Individuals who bike for competition are four times more likely to be seriously injured. Most of the injuries result due to accidents in downhill races, such as flat tires and mechanical problems. Other factors are caused from hitting a rock or bump at high speeds, losing traction, and control on turns.

4.1.3 Preventative Measures

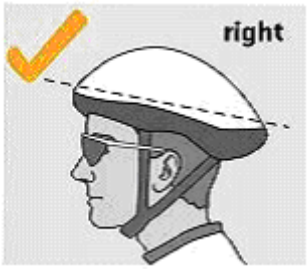
Many injuries can be prevented simply by a rider knowing his or her own limits and ability. Other preventions such as equipment and its maintenance can be used as well as common sense.

The importance of bike maintenance, bike-handling skills, and helmets are emphasized. Most helmets do not provide protection to the face, but recent developments have redesigned the helmet to provide for better facial protection. Even though helmets are worn by 80%-90% of off-road cyclists, head injuries still result because it isn't fully developed yet. However, there is a 75% reduction in risk if a rider wears a helmet correctly (Figure 11). [19]

[19] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1



a)



b)

Figure 11: Correct Fit of a Helmet[20]

Data has shown that there is a 50-50 chance of a rider having a head injury in any type of accident. When a rider crashes they are likely to land on their shoulders and head, because in most cases, the top tube of the handlebars will trap their legs. The probability is that even the most careful of cyclist's will crash. Statistics indicate that approximately every 4,500 miles on average a rider will have an accident. When a rider does crash, it is essential that they have proper head protection. About 75% of the 1,400 annual deaths caused by cycling accidents are due to head injury. While protective gear is available for the chest, shoulder, and extremity padding, these can prevent small injuries, but they do not have the ability to prevent serious injury.[21]

[20] Hill, Lindsay, Tom Sutton, and Joan McIntosh. "Bike Sense." Greater Victoria Cycling Coalition. Pg. 1
[21] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

Table 3: Injury location and percent occurring in male and female cyclists[22]

Injury (location)	Male (%)	Female (%)
Neck	44.2	54.9
Knees	40.1	43.7
Groin/Buttocks	37.4	33.9
Hands	29.6	33
Shoulders	24.8	37.5
Back	31.6	28.6
Feet	13.9	16.5
Thighs	7.5	9.8
Elbows	4.1	5.8
Head	4.1	5.3
Hips	4.8	3.6
Ankles	3.7	3.6
Achilles	2	5.8

A graphical representation of the data in Table 3 is shown in Figure 12.

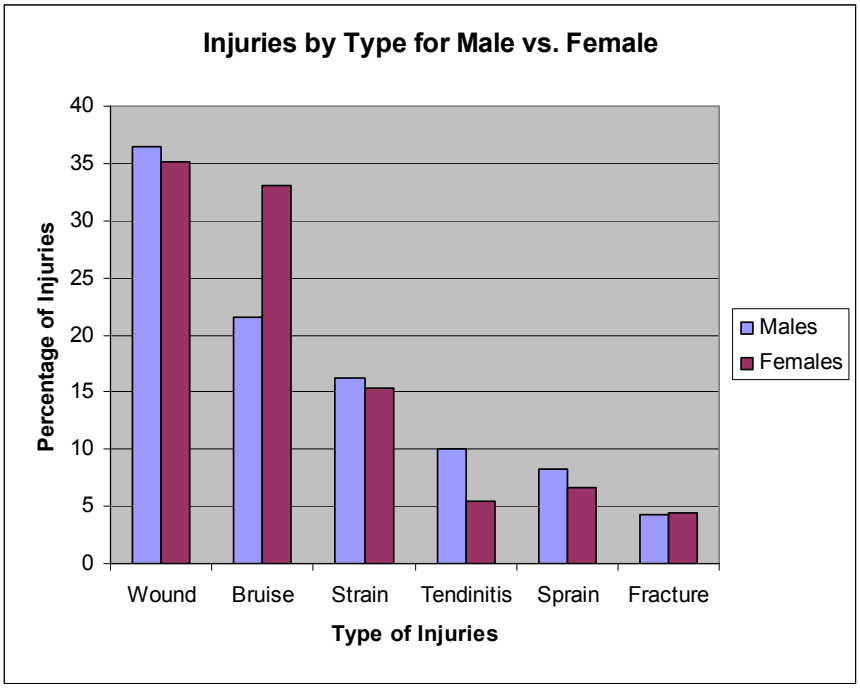


Figure 12: Graphical Representation of Table 3

[22] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

Table 4: Percent of Cycling Injuries by anatomical site for male and female cyclists receiving medical treatment for injuries[23]

Injury (location)	Male (%)	Female (%)
Neck	44.2	54.9
Knees	40.1	43.7
Groin/Buttocks	37.4	33.9
Hands	29.6	33
Shoulders	24.8	37.5
Back	31.6	28.6
Feet	13.9	16.5
Thighs	7.5	9.8
Elbows	4.1	5.8
Head	4.1	5.3
Hips	4.8	3.6
Ankles	3.7	3.6
Achilles	2	5.8

A graphical representation of the data in Table 3 is shown in Figure 12.

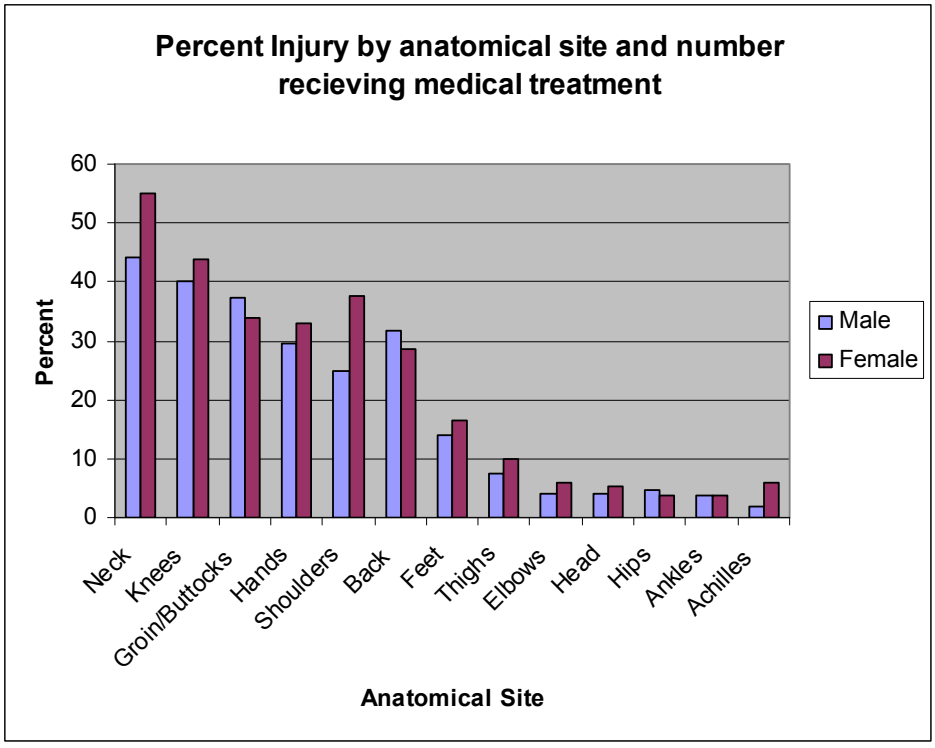


Figure 13: Graphical Representation of Table 4

[23] Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries."Pg.1

4.1.4 Terrain Influenced Injuries

Environmental factors also cause injuries for cyclists. As the cool rains of spring fade into the blistering hot days of summer, cyclists must adjust to the changes in heat. Excess heat can cause problems for any rider no matter what their experience level is. Water loss affects the circulatory system, which is about 70 percent water. When water is removed from the blood, its ability to carry sufficient nutrients to the working muscles and its ability to distribute heat to the skin to be vaporized are reduced. When the body's cooling components fail, this is because of dehydration, and these results in heatstroke. This can cause a rider to become very weak and exhausted. In serious cases the rider may even faint. When heatstroke occurs, a rider should stop riding and move to a cool area. Large amounts of water should be immediately consumed and wet towels should be placed over the body. Medical help should be sought if their condition does not improve.

When a rider is above 6,000 feet, breathing becomes a preventive factor. In higher altitudes the atmospheric pressure decreases and the air is thinner, so there is less available oxygen. Riders can experience nausea, headache, or feel very tired. Symptoms will usually disappear between 24-48 hours. The sun also has more power to burn you at a higher altitude, so biker's should wear protective sunscreen. The more a rider trains in higher altitudes, the more the body will get used to the effects. Respiratory distress goes down because your body will start producing more red blood cells to help carry the

oxygen. The process of oxygen transfer from the lungs to the tissues rapidly increases. So over time, a rider's performance will improve.[24]

4.1.5 Case Studies: Cycling

Two studies conducted in Germany observed participants that ranged from ages 8-81 years. The studies found that biking is most popular among young adults between the ages of 22-36. About 80% of competitors in the National Off-Road Bicycle Association (NORBA) are between ages 19-44. These two studies compared injuries of mountain bikers to other cyclists. The results showed that mountain bikers tended to be older than other cyclists and that a bigger percentage of them were male. [25]

In all injury studies, there has been shown to be a dominant amount of male cyclists, about 75-85% of the injured reports. This is most likely caused by a higher male participation. NORBA calculates that about 89% of cyclists are male. [26]

Data has found that in the US in the year 2000, about 13.4 million adults own mountain bikes and about 7.l million actually ride their bikes off-road. As shown in Table 4.3, in the last few years, male participation in the cross-country race has decreased while participation in the downhill race is becoming more popular. This popularity has resulted in the NORBA National Championship Series (NCS) race being established. These races consist of a downhill race as the grand finale of a series of 4 day races. This has influenced a change in the bikes to become extremely tailored with designs that are specialized for each particular race. Another race has been added to increase spectators, called the Short Track race. This is when competitors use a mass start format and race

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[24]

[25] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.
[26] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

multiple laps around a 1 km circuit for about 30 minutes. A dual slalom is when a pair of riders challenges each other to a head-to-head race on a course.[27] Table 5 and 6 represent the amount of participation of men and women in the National Off-Road Bicycle Association National Championship Series in 1996 and 2000.

Table 5: Participation in cross-country, downhill, and dual slalom races at the National Off-Road Bicycle Association National Championship Series, 1996 [28]

1996		
Type of Race	*Men (%)*	*Women (%)*
Cross-Country	65	65
Downhill	25	23
Dual slalom	10	12

A graphical representation of the data in Table 5 is shown in Figure 14.

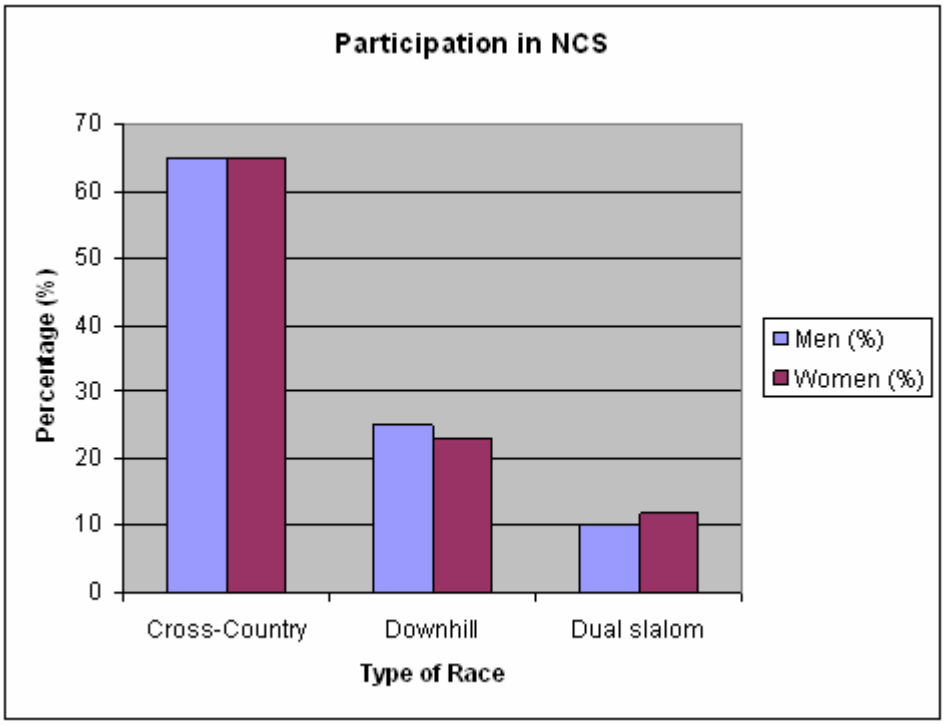


Figure 14: Graphical Representation of Table 5

[27] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.
[28] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

Table 6: Participation in cross-country, downhill, and dual slalom races at the National Off-Road Bicycle Association National Championship Series, 2000[29]

2000		
Type of Race	*Men (%)*	*Women (%)*
Cross-Country	46	58
Downhill	42	30
Dual slalom	12	12

A graphical representation of the data in Table 6 is shown in Figure 15.

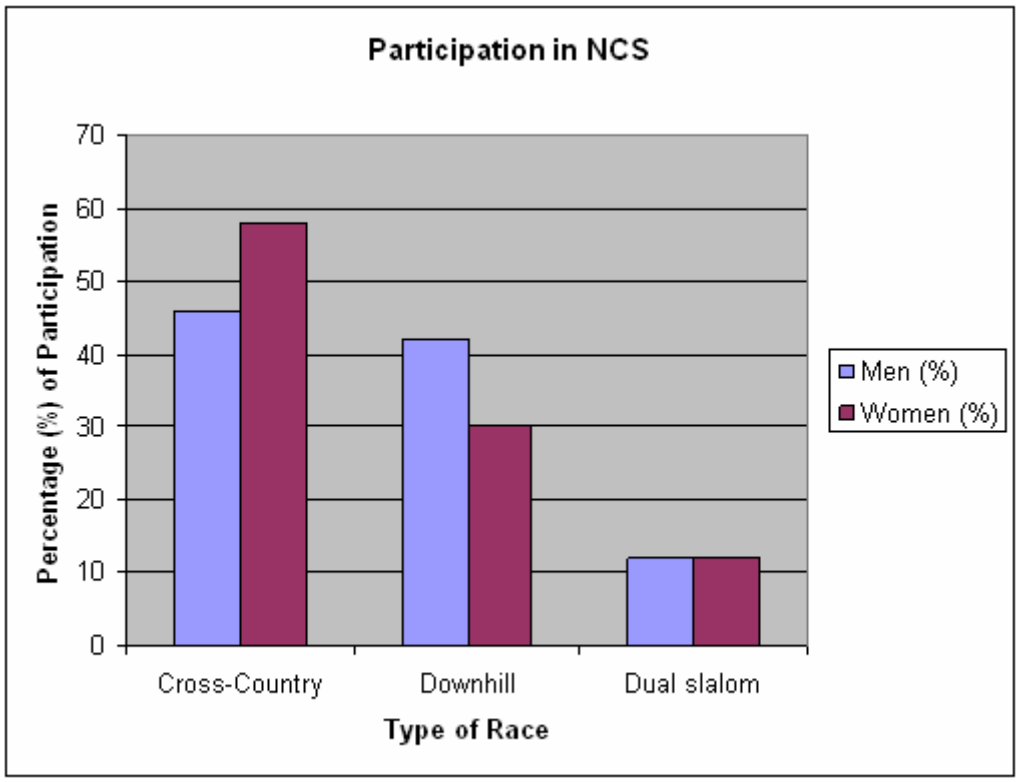


Figure 15: Graphical Representation of Table 6

[29] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

Little information is provided for overuse injuries, but there are a few questionnaire-based surveys available on the survey. In one German study, where 840 mountain bikers were interviewed, it was found that about 90% of them reported constant overuse injuries. Another study it was ascertained that of 208 bikers surveyed, 45% of them suffered from overuse injuries. Mountain bikers suffered injuries commonly in their hand and wrist, neck, lower back knee, and saddle regions. In one study of 265 mountain bikers in the US, 37% suffered from back pain, 30% of knee pain, 19% of wrist pain, and 19% of numbness of the hand. In yet another study, that used 115 of top Swedish mountain bikers, they suffered from similar injuries and noted that this was due to excessive training, bad saddle position, improper clothing and shoes, and rough terrain. It was cited that excessive training, cold weather, improper stretching and gear, and rough terrain all provoked these types of overuse injuries.[30] [31]

Questionnaire surveys have shown that participants have reported that 50-90% of them have suffered from acute injuries. Annual prospective studies held by NORBA in the NCS race from 1994-2001, have found that the overall injury rate of 0.45% was found in cross-country, downhill, and dual slalom events. A retrospective study has shown that injuries in recreational bikers from 1992-1994 have an injury rate of 0.30%.[32]

A mountain biker's ability to maintain control over rough terrain and a series of obstacles can prove to be difficult for even the most experienced biker. Injuries can be related to the terrain, the biker, and the bicycle itself. The most serious biking related injury is a result of quick deceleration that can result in a biker being thrown over the

[30] Frobose I, Lucker B, Wittmann K. "Overuse symptoms in mountain bikers: a study with an empirical questionnaire." Pg. 311-315
[31] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.
[32] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

handlebars. This type of injury commonly occurs in the downhill race. It results in trauma to the head, torso, upper extremity, shoulders, and even the head, neck, and the face region. This type of fall is a cause of riding over a bump, incorrect landing after the rider has taken a jump or extreme pressure on the brakes. When a rider becomes fatigued they sometimes can no longer hold on to the handle bars, which could also result in a forward fall. Reports have shown that collisions with trees, rocks, or barricades are less likely to happen than falls. Collisions can also occur when riders ride too closely to each other in packs. [33]

Injury can result due to failure of the bicycle components. Four different studies have shown that bicycle failure accounts for 6-16% of injuries. Flat tires have been the most prevalent problem. Other problems occur due to failure of brakes, chains, forks, handlebars, pedals, cranks, and suspension parts. Padded clothing and helmets are worn to prevent most of these injuries. While these measures can help, there is still room for injury. For instance, clavicle fractures and glenohumeral dislocations can still happen even if shoulder protectors are worn. Laceration in the prepatellar bursa occurs despite use of knee protectors. [34]

[33] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.
[34] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

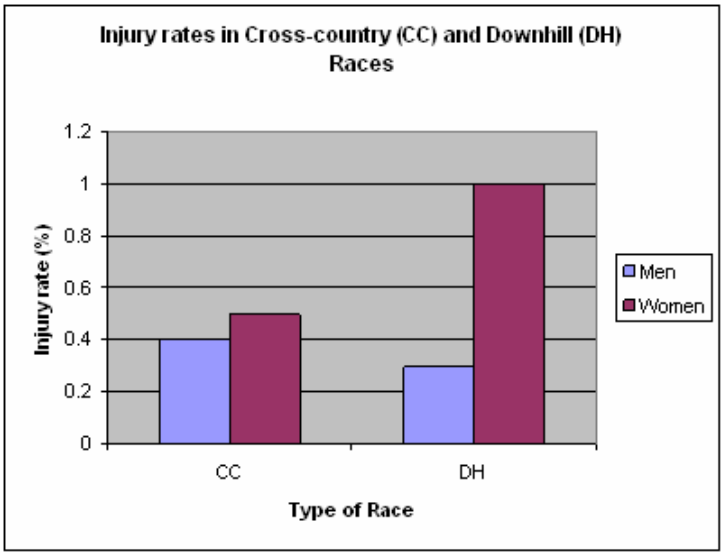


Figure 16: Injury rates in amateur and professional cross-country (CC) and downhill (DH) competitors at the National Off-Road Bicycle Associations National Championship Series races, 1994-2000[35]

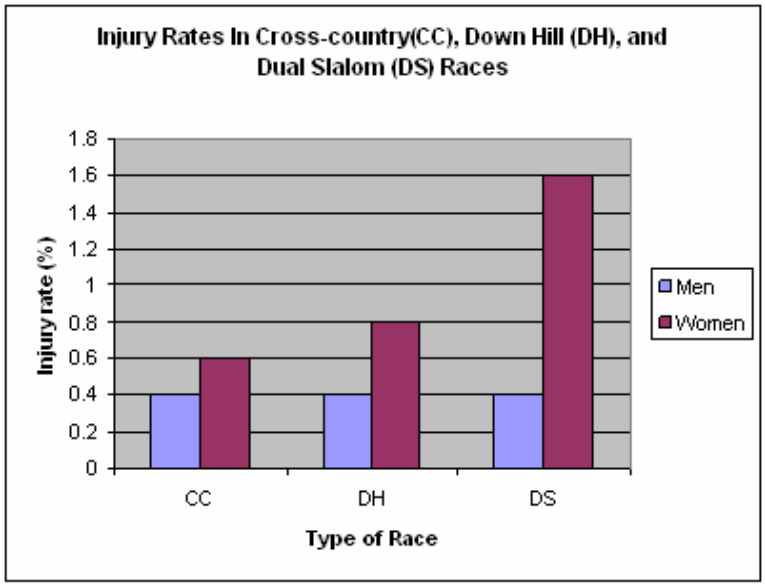


Figure 17: Injury rates in amateur and professional cross-country (CC) and downhill (DH) and Dual slalom (DS) competitors at the National Off-Road Bicycle Associations National Championship Series races, 1994-2000 [36]

[35] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.
[36] Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries."Pg.523-535.

4.2 Introduction to Alpine Skiing

Alpine skiing has been a progressive sport in the world for many years (Figure 18). It became a major trend in Europe where enormous mountains are easy to come by. As with athletic sports that have originated overseas, the sport made its way into the United States. With its growth of support now traveling across the globe, many details of the sport developed in a similar manner. Ski resorts seemed to multiply in the early 1900's in the United States. Equipment standards grew from archaic, to semi-sophisticated, to their current state where considerable engineering work may go into a single piece of any equipment component.

Figure 18: Alpine Skiing[37]

Early skis were constructed of wooden planks, with hardly any consideration to the design. Binding the boots to the skis was simple and permanent. Skiers found the need to take their boots off of their skis in order to last for longer periods than just one

[37] "Skiing News." Pg.1

run. New designs for clamps were created to allow the skier to take their boots in and out, but they still remained unsophisticated. Up to this point, the boots used were crafted mainly out of leather, which was soft and transferred minimal forces to the ski. As skiers began racing, and found a need to be on top of their game, the industry improved boot designs. Stiffer boots transferred lateral, fore, and aft forces to the ski which made drastic developments in skiers' abilities. With boots and bindings being improved, skis were now a main concern. Stiffness in every aspect was taken into consideration to find how to optimize the ski's performance. A huge discovery to torsional stiffness in skis was the use of unidirectional fiberglass. Its use upgraded torsional stiffness while allowing the ski to flex laterally, however, with these enhancements to ski products, there developed a few problems. The skis were turning much harder creating larger forces through the bindings and boots. The bindings were not releasable and with the boots being stiffer, forces were transferred to the body. These forces were large enough to cause injuries to the lower leg, including ankle, shin, and knee injuries. To bounce back from these problems, the ski industry began designing releasable bindings. This type of bindings will release if a force is large enough to damage the body. As a result, taller boots to decrease moment forces on the shin were implemented. In recent years, skis have undergone their greatest advancement. The rise of CNC machining has made creating molds for skis have never been easier. Earlier designs were extremely costly which in part was what hindered innovation in ski and boot designs. Now, shaped skis allow skiers to turn on a parabolic edge, which actually turns the ski itself, without much effort from the skier. As a result of the development in the sport, one can only wonder where innovation and new technology will lead to in new ski, boot, and binding designs.

4.2.1 Injuries in Skiing

Alpine skiing is a popular sport, but like most sports on any day, 3-4 out of 1,000 skiers will sustain an injury that requires medical attention. That's about 165,000 people that sustain serious injuries yearly. Skiers often reach high speeds while skiing down busy slopes through trees. Most ski injuries are caused from falls, collisions, or overuse injuries. Heavy and loose snow increases the risk of lower extremity injuries because the skis can get stuck in the snow and cause knee and ankle injuries. Skis can slide out from under a skier due to icy conditions and this can further increase the rate of upper extremity injuries. Skiing can result in a serious trauma or death if an occurrence of an avalanche, particular medical condition, or impact with a solid object were to occur. An avalanche can occur if a person skis on an unstable snowcap or an overhanging cornice. According to the National Ski Association, in 2000, 34 people died and 39 suffered paralysis. Inside Track estimates ski-related injuries to the knee alone exceed more than $250 Million dollars every year in the US in medical bills.[38]

Since the 1970's the overall ski injury rate has decreased by about 50%. Lower limb fractures have had the biggest decrease in injury rate since the development of the release binding systems and the plastic-shelled alpine boots. Contrary to these decreasing rates, the rates of shoulder, thumb, and head injuries have not decreased. The rate of serious knee injuries, especially ACL tears has gone up an astonishing 240%. Research is being done to find methods under which the binding would release under ACL-injury-inducing falls, but not have the binding prematurely release under normal conditions.

[38] Gundel, Md, Jeff. "Common Alpine Skiing Injuries." Pg. 1

The new and improved style of shaped skis accounts for about 90% of ski sales, but it puts you at a higher risk for knee injuries. [39]

4.2.2 Knee Injuries

Approximately 30-40% of injuries in alpine skiing affect the knee. They involve the medial collateral ligament, anterior cruciate ligament, and the meniscus. Injury to the medial collateral ligament is the most common and accounts for 20-25% of all injuries, mostly seen in beginners to intermediate skiers. It is caused by excessive force applied to the knee joint, mainly as a result of a fall, crossing of skis, and the snowplow position (Figure 19).

Figure 19: Snow Plow Position of Skis[40]

Torn ACL's account for 10-15% of ski injuries. ACL injuries are related to a "phantom-foot" fall, as labeled by the National Ski Patrol, which are based on the

[39] Gundel, Md, Jeff. "Common Alpine Skiing Injuries." Pg. 1
[40] Langran, Dr, Mike. "Knee Injuries." Pg. 1

analysis of 14,000 video clips. The “Phantom foot fall” happens when the tail of the ski along with the back of the boot, acts as a lever to apply a unique combination of twisting and bending force across the knee joint (Figure 20). The resultant is a torn ACL. [41]

Figure 20: The "Phantom Foot Fall"[42]

[41] Gundel, Jeff MD. "Common Alpine Skiing Injuries." Pg. 1
[42] Langran, Mike Dr. "Knee Injuries." Pg. 1

4.2.3 Treatment for a Torn ACL

In ACL surgery, the remnants of the torn ACL (See Figure 21) must be removed and a similar ligament around the knee will be put in its place. The central part of the patellar tendon, some hamstring tendons, or an allograft from a cadaver can be used.

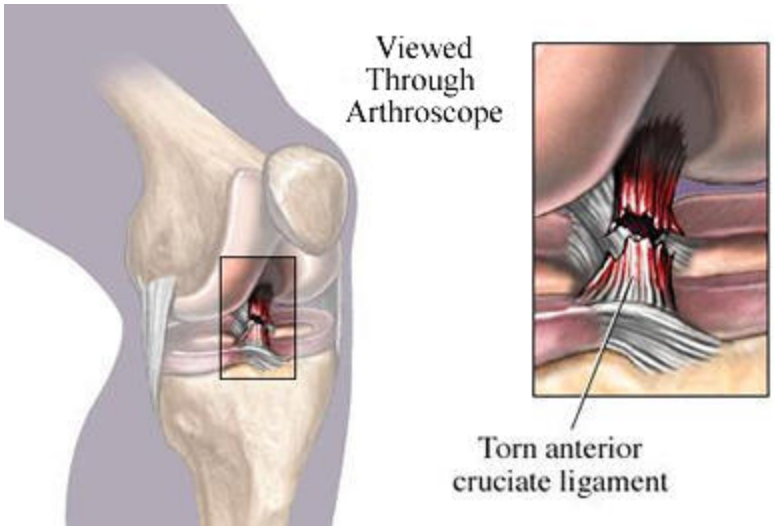


Figure 21: Torn ACL[43]

For a graft of the patellar tendon (See Figure 22), the main 1/3 part of it is removed along the bone at both ends of the ligament. The bone blocks at the ends allow the graft to be fixed and heal fast in tunnels that are drilled into the femur and tibia. The patellar tendon is what connects the tibia to the patella and it allows the quadriceps to move the knee. This procedure was the first successful process, and this is still used in practices today.

Parts of the hamstring known as the gracilis and semitendinosus muscles are what help to flex your knee. They have long tendons that insert into the tibia. These can be removed, doubled over, and then replaced. This type of surgery only requires small holes

[43] "Arthroscopy of the Knee." Pg. 1

to be made in the femur and tibia to attach it. This is more challenging than then using the patellar tendon because they don't have blocks of bones at both ends.

An allograft uses pieces of frozen patellar tendon from humans. This has an advantage because you don't have to use the patellar tendon or hamstring tendons. The procedure is much faster, but the graft can carry infections and graft failure rate is much higher.

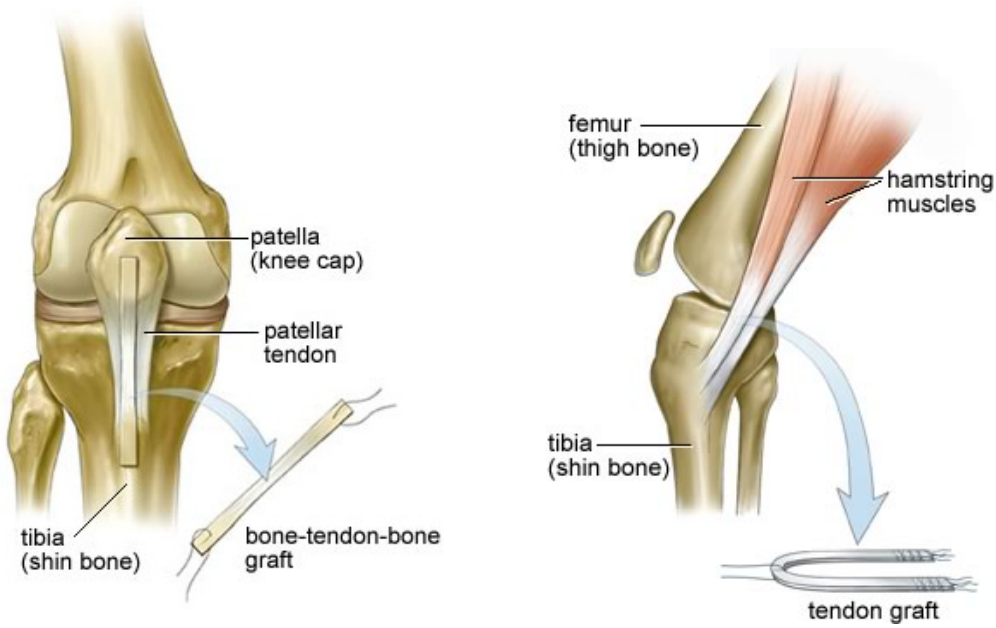


Figure 22: Grafting Techniques of ACL[44]

ACL surgery initially begins with an arthroscopic examination of your knee. It involves making small incisions that are ¼ of an inch into the knee. Fiber optic lights sources are used to look at the inside of the knee with a video camera (Figure 23).

[44] "ACL Knee Surgery Explained." Pg.1

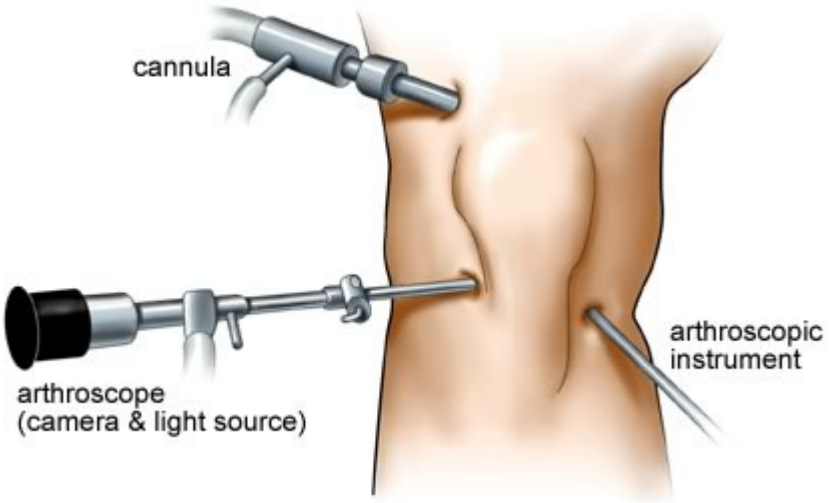
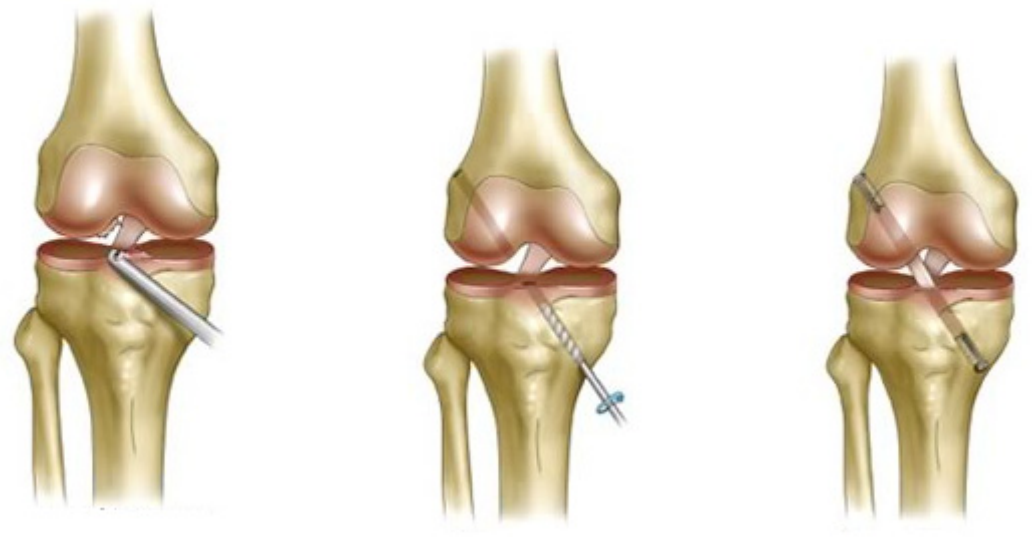


Figure 23: Fiber Optics to View Knee[45]

The remnants of the torn ACL are removed with a high-speed shaver. Using a high-speed burr, the surface of the intercondylar notch where the ACL attaches is prepared so that proper location can be seen.

Tunnels are drilled through the femur and tibia to all for the place where the graft is to be placed. Another incision is made about 2-3 inches long to harvest the graft from either the patellar or hamstring tendons. The graft is then prepared by using surgical sutures through the graft to pass it through the tunnels. After that, it is fixed in place. [46] This procedure is shown in Figure 24.

[45] "ACL Knee Surgery Explained." Pg. 1
[46] "ACL Knee Surgery Explained." Pg. 1



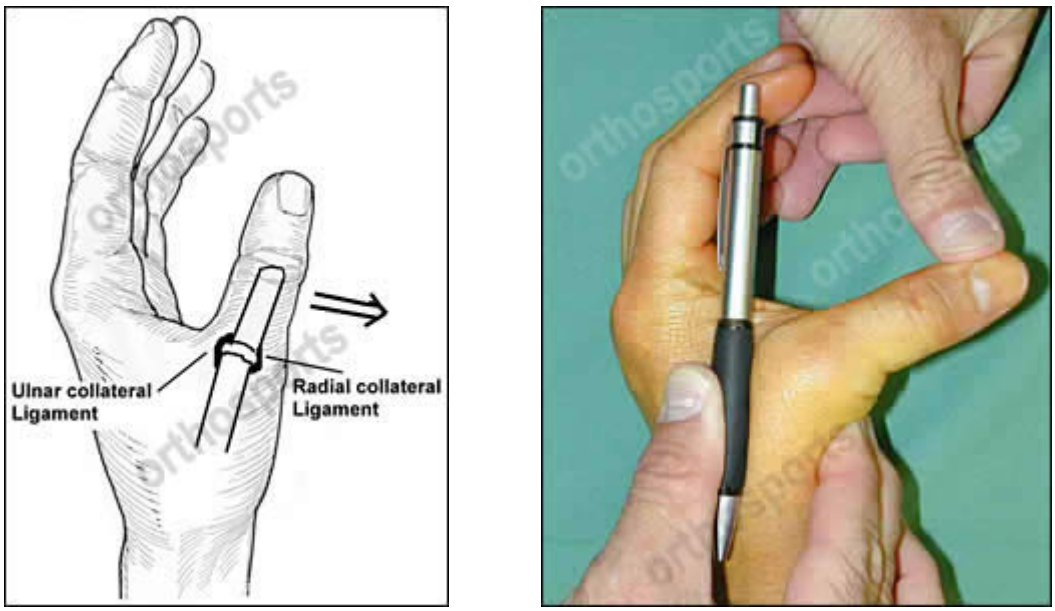
a) b) c)

Figure 24: Figure a) Removal of ACL Figure b) Drilling of Tunnels Figure c) Secured Graft [47]

4.2.4 Skier's Thumb

Skiers thumb is one of the most common injuries among skiers as well (Figure 25). Skier's thumb is an acute injury to the Ulnar Collateral ligament of the thumb. If a ski pole gets caught between the thumb and index fingers, a tear of a thumb ligament can result. If a skier falls, they will release the pole and put their hand behind them to prevent their fall. If the thumb catches the snow, the weight of the skier and the high speeds will apply a force across the joint that strains the ligaments. Fractures can also result. [48]

[47] "ACL Knee Surgery Explained." Pg. 1
[48] Gundel, Jeff MD. "Common Alpine Skiing Injuries." Pg. 1



a) b)

Figure 25: Figure a) Normal Thumb Figure b) Thumb bent away from fingers[49]

The treatment for this type of injury is a fiberglass cast. The splint is used for 4-6 weeks. If the joint is unstable or the fracture is displaced, surgery must be used. In surgery the ligament is repaired back to the bone using a bone anchor or the fracture is fixed with a wire or screw.

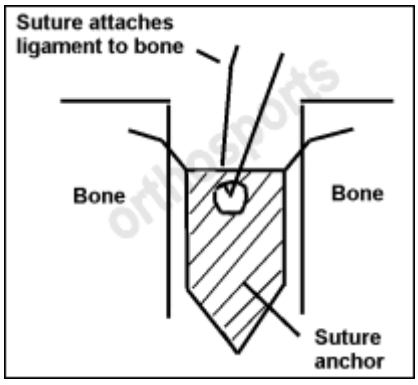


Figure 26: Suture Anchor attached to ligaments[50]

[49] "Skiers Thumb." Pg.1
[50] "Skiers Thumb." Pg. 1

4.2.5 Age Factors

In ski injury reports for 1991-1992, by the Blackcomb ski patrol, they found that children ages 7-12 and teens ages 13-17 have a higher risk of skiing injury compared to people ages 18 and older. Head injuries accounted for 17% (ages 7-12) and 22% (ages 13-17) of injuries in children and teens. Incorrectly adjusted equipment is a significant risk factor for young skiers. Prevention programs should include promotion of well-adjusted equipment, improvement of skill level, education of parents, application of recognized standards for adjusting rented equipment and use of the binding testing devices in ski shops. Ski areas have many programs that can increase ski safety. Alpine lessons are offered and greatly encouraged.[51]

4.2.6 Case Studies: Skiing

In a recent 2002 study conducted by The Journal of Trauma Injury, Infection, and Critical Care many new developments in skiing and snowboarding have taken place. The sports now have about 13 million participants. Together both skiing and snowboarding account for around 57 million ski area visits. They estimate that the growth of snowboarding since 1988 is close to 331%. This drastic increase is most likely part of the cause for the 40% decrease in skiing.[52]

Even with these large numbers engaging in the dangerous sport (Refer to Table 7), the death rate per million is still relatively low compared to biking. However, the sport is dangerous not for its high death toll, but for the number of injuries that require emergency room visits. It is estimated that nearly 100,000 skiers and snowboarders each

[51] "Snow Sports." Harborview: Injury Prevention and Research Center Pg. 1
[52] Matsumoto, Kazu, Miyamoto Kei, Sumi Hiroshi, Sumi Yasuhiko, and Shimizu Katsuji. "Upper Extremity Injuries in Snowboarding and Skiing: A comparative Study." Pg. 1

year sustain injuries that require an emergency room visit. Many of the deaths that actually do occur in skiing and snowboarding stem from these injuries into traumatic brain injuries (TBI).[53]

Comparing today's statistics to the past two decade's, there is a trend that corresponds to the changes in the industry. Statistics can be shown in Table 8. Skiers sustaining head and neck injuries have remained the about the same over the past twenty years. With the use of helmets and the incredible safety advancements made with products one might think the statistics would decrease. But consideration for the style of skiing must also be made. Inverted arials and other technical tricks have made there way onto most any mountain, are responsible for many of the head and neck injuries sustained. Snowboarders, on the other hand, have seen an increase over the past two decades.

To further understand these statistics this study broke down injuries by demographics, comparing age, gender, race, site of injury, and types of products being used. They also compared these numbers to the total denominator population to further enhance their findings.

[53] Matsumoto, Kazu, Miyamoto Kei, Sumi Hiroshi, Sumi Yasuhiko, and Shimizu Katsuji. "Upper Extremity Injuries in Snowboarding and Skiing: A comparative Study." Pg. 1

Table 7: Number of Injuries in Skiing due to Gender, Race, Locale, and Mechanism[54]

Gender	*Skiing Number of Injuries*	*Snowboarding Number of Injuries*
Male	46,180	45,289
Female	31,125	16,686
Not Stated	0	30
Race		
White	40,541	42,134
Black	380	597
Other	1,437	2,332
Not Stated	34,946	16,942
Locale		
Skiing Resorts	71,208	49,011
Other Places	2,077	5,040
Not Stated	4,019	7,954
Mechanism		
Simple fall	41,045	33,562
Fall from lift	1,042	276
Collision(object)	2,447	1,041
Collision(human)	2,234	1,214
Other	11,849	7,825
Not Stated	18,687	18,084

[54] Matsumoto, Kazu, Miyamoto Kei, Sumi Hiroshi, Sumi Yasuhiko, and Shimizu Katsuji. "Upper Extremity Injuries in Snowboarding and Skiing: A comparative Study." Pg. 1

Table 8: Number of injuries due to injury type, body part affected, and treatments in skiing and snowboarding[55]

Injury Type	*Skiing*	*Snowboarding*
TBI	5,552	5,156
Soft Tissue	37,916	25,041
Dislocation	4,087	3,248
Fracture	20,356	22,064
Laceration	4,310	3,097
Other	5,069	3,199
Not Stated	15	198
Body Part		
Head/Face	12,146	10,252
Shoulder	12,067	9,083
Torso	9,880	7,187
Arm	5,089	10,304
Wrist	3,021	11,104
Hand/Finger	5,455	2,450
Knee	17,561	3,962
Other lower extremity	11,483	7,463
Other body part	603	130
Not stated	0	69
Treatment		
Treat/release	73,741	59,481
Hospital	3,442	2,402
None	61	61
Death	61	0
Not recorded	0	61

[55] Matsumoto, Kazu, Miyamoto Kei, Sumi Hiroshi, Sumi Yasuhiko, and Shimizu Katsuji. "Upper Extremity Injuries in Snowboarding and Skiing: A comparative Study." Pg. 1

4.3 Introduction to Rock Climbing and Mountaineering

The sport of rock climbing and mountaineering is not a new addition to the realm of modern sports. Since people have been getting outside to exercise and enjoying the outdoors, they have been impelled to scale rock walls or hike mountains large and small. Before any large developments in the sport, those who participated did so by hiking or "free-climbing", which is done with no ropes or gear to aid an ascent. From those times, equipment and the level of expertise in the sport is rapidly rising. Rock climbing equipment started with the emergence of braided hemp ropes, which have now evolved into nylon and other stronger fibers. Aid gear, simply known as "gear" to rock climbers, grew from slinging chock stones to mechanical devices crafted from high quality metal. Other mountaineering equipment has evolved in the same way. Backpacks, harnesses, and even shoes are continually being improved to increase comfort and performance. Foam in backpacks as well as harnesses are varied to adapt to different body types as to not conflict with ones hiking/climbing ability. Climbing and hiking shoes are made from much different molds than what would be used for a basketball or football shoe. The shoes are shaped to provide maximum traction in almost any application. Also, the materials used have come a long way from the traditional leather boots first used. The rubber currently used, is constantly being upgraded to create higher coefficients of friction between the shoe and hiking/climbing surfaces. About 300,000 people in the U.S. have been estimated to climb a rock wall, but with this increase in participation come an increase of injuries. This increase calls for the need for awareness of the dangers involved whether you are a beginner, novice or an expert climber (Figure 27).

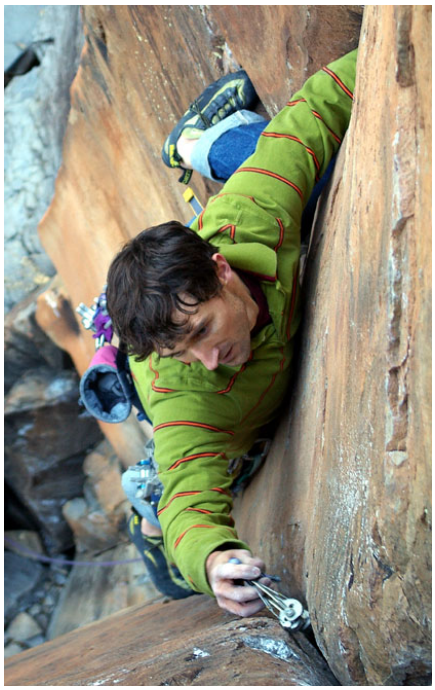


Figure 27: Rock Climber [56]

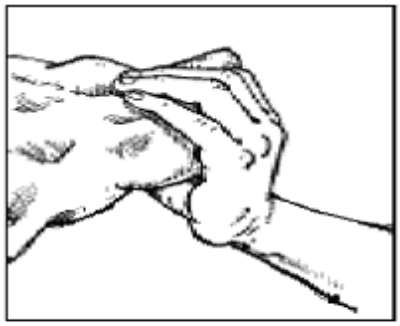
Rock climbing is a demanding and challenging sport. A climber must have strength in the shoulders, back, hips, and arms. Being mentally prepared for a sport like this is important too. You must have an awareness of your whole body before you can make a next move while climbing on the rocks. Trying to do all this and maintain your balance is very difficult.

Surveys have found that about 75 percent of climbers have some type of injuring during their climbing careers. This injury is usually related to a climbers experience vs. the difficultness of the individual climbs. Deaths are usually associated with failed equipment and human error.[57]

[56] "Rock Climbing." Pg. 1
[57] Acquaviva, John Phd. "Rock Climbing." Pg. 1

4.3.1 Injuries Sustained by the Function of the Hand

Rock climbers depend on the digital and upper-extremity strength and tactile ability to climb on ledges and rock faces, using four different grip techniques dependent upon the terrain. Large pressures are forced on the tissues of the digits, hand, and forearm, through the four different grips. These pressures result in different acute and chronic injuries. The hand is the most common place of injury in rock climbers. While some injuries may be minor, others can cause serious problems for the climber's safety. This is when treatment, rehabilitation, and prevention measures are needed.

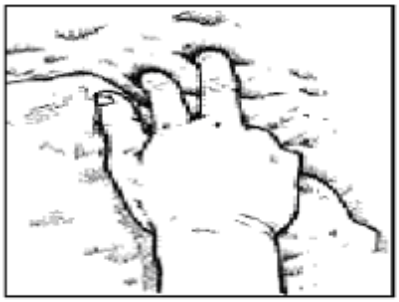


a)

In the open grip the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints are held in varying degrees of flexion. As the climber progresses upward, this grip often turns into a cling grip

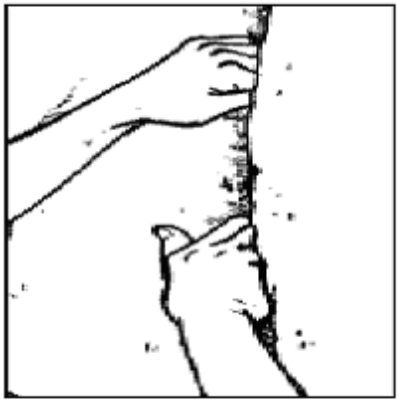
b)

The cling grip is the most common and most painful of rock climbers' grips. Hyperextension of the DIP joints and flexion of PIP joints is evident.



c)

In the pocket grip, the rock climber places one or two fingers into small holes in a rock face. The flexor tendons may support the most or all of the climbers weight



d)

In crack climbing, the climber locks his or her digits into crevices between rocks. This type of climbing is associated with joint dislocations and with digital avulsion amputations, which can occur with a sudden slip or fall.

Figure 28: Figure A) Open Grip, Figure B) Cling Grip, Figure C) Pocket Grip, Figure D) Pinch Grip[58]

Figure a represents the open grip, which is used when a climber grasps wide or large handholds. This grip then turns into the cling grip which is represented in Figure b.

[58] Jebson, Md, Peter L., and Curtis M. Steyers, Md. "Hand Injuries in Rock Climbing: Reaching the Right Treatment." Pg.1

The distal interphalangeal joint hyper extends as a downward force and is exerted downward as the climber pulls their body upward. This is the most painful grip type. Most of the force is placed on the fingertips and can cause strain on the digital flexor tendons, adjacent sheath, and pulleys. Climbers are often encouraged to strengthen these muscles to prevent injuries. One example is by practicing the cling grip by doing one or two finger pull-ups on doorjambs or training boards. The third type of grip shown in Figure c is the pocket grip. This is when one to two fingers are placed in small holes. This grip requires the flexor tendons to support almost all of the climber's body weight. The Pinch grip shown in Figure d is used when the climber grabs a part of the rock between the thumb and fingers.[59]

While hand injuries are the most common injuries rock climber's experience, they can be treated usually with rest, anti-inflammatory medication, and splinting and taping. However, certain injuries require medical and surgical involvement. These types of injuries include flexor tendon strains, pulley strains, and ruptures. Climbers use training that key on strength, conditioning, and flexibility to help prevent these injuries.

Soft-tissue injuries include fingertip injuries, which are the most frequent type of injury to the hand. Fingertip injuries include maceration and the splitting of the skin due to large amounts of pressure and friction on the skin. Treatment for these types of injuries should involve rest, wound care, and use of preventative gear. While rubber pads and sleeves should be worn for protection, gloves should not because they can cause problems for the climber when trying to secure a handhold.

[59] Jebson, Md, Peter L., and Curtis M. Steyers, Md. "Hand Injuries in Rock Climbing: Reaching the Right Treatment." Pg.1

Another type of injury in the hand is includes the digital flexor tendons. Injuries that affect the flexor tendons are tendonitis, strains, and rupture. The flexor tendons tend to be injured during the cling and pocket grips shown in Figure b and Figure c. The inflammatory response due to reoccurring stress is a condition known as flexor tendonitis. The patient can have pain and swelling from the palmar surface of the digit and may even be painful as far as the forearm. This condition causes the patient's active flexion to be limited. The treatment for a patient who has flexor tendonitis should rest, take anti-inflammatory medication, and perform exercises. In rare cases, when patients who have chronic tendonitis and all other treatment options don't work for them, they will have a Corticosteroid injection. This type of injection must be performed with great care because it can result in a ruptured tendon. [60]

Flexor tendon strain, or better known as "climbers finger" is when a climber experiences acute pain on the FDS tendon insertion during a hard cling grip (Figure 29).

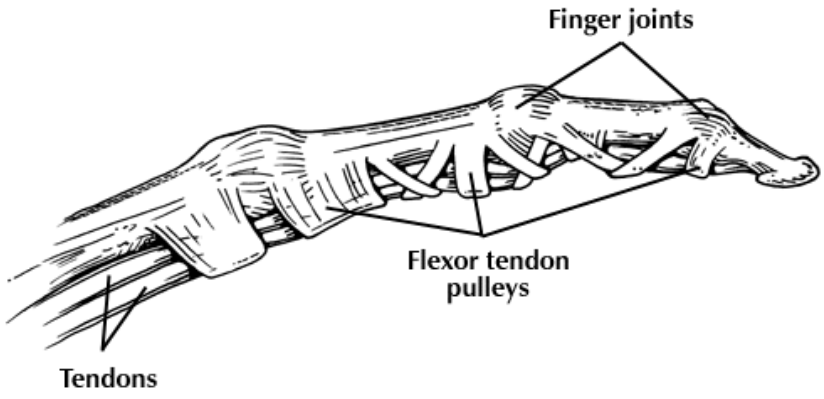


Figure 29: Flexor Tendon Pulleys[61]

[60] Jebson, Md, Peter L., and Curtis M. Steyers, Md. "Hand Injuries in Rock Climbing: Reaching the Right Treatment." Pg.1
[61] Jebson, Md, Peter L., and Curtis M. Steyers, Md. "Hand Injuries in Rock Climbing: Reaching the Right Treatment." Pg.1

A climber who suffers from flexor tendon strain should rest, take anti-inflammatory medication for digital swelling, and perform exercises. When full range of motion is acquired again, a strengthening program should be performed to slowly rehabilitate the climber until they are ready to return to climbing. Many climbers use digital taping to help prevent flexor tendon injury.

Rupture has the potential to occur during climbing. FDS tendon rupture usually is common with the cling grip, while FDP tendon rupture is common with the pocket grip. Climbers tend to experience acute pain during a grip along with tenderness at the FDS or FDP tendon insertion, digital swelling, and PIP or DIP joint. In a rupture, the end of the tendon retracts and this causes it to swell and become tender. Rupture calls for surgery to reconnect the tendon.[62]

One study shows that 40% of professional climbers rupture their A2 pulley. This is due to the constant stress on the pulley when using the cling grip. A climber's longest and ring fingers are involved in this rupture. An electromagnetic resonance imaging scan may have to be used to recognize the rupture.[63]

Carpal Tunnel Syndrome is a condition that affects about 25% of climbers. This happens when the median nerve of the hand is compressed causing pain and numbness (See Figure 30).

[62] Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Pg. 1369-1372.
[63] Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Pg. 1369-1372.

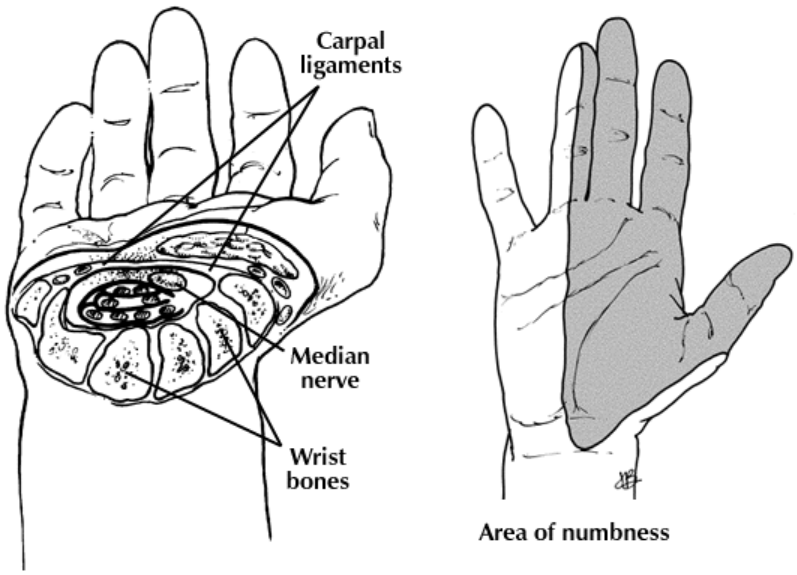


Figure 30: Carpal Ligaments[64]

Prevention of these types of injuries should begin with educating the climbers for risk factors involved in climbing. Light training should be done when a climber first feels a pain and should have adequate rests in between climbs. Proper conditioning and warm ups are also integral steps that must be done to take care of sprains, strains, and other injuries. New climbers so enter the sport slowly because they are more susceptible to over use injuries. This sport challenges your whole body, so muscles that aren't normally used will be. This requires that a climber had a routine of proper stretching of the back, shoulders, legs, neck, and arms. Proper gear must be used to support and protect your body. Taping between finger joints, around wrists, fingers, and elbows add support to protect the tendons. Skin abrasions can be reduced by taping the back of your hands and writes in a figure eight pattern. A climber must inspect their gear regularly and replace any worn equipment. Climbing shoes are also an important part of proper

[64] "Carpal Tunnel Syndrome." American Academy of Family Physicians. Pg.1

equipment; the tops are usually leather and are only finished on the outside. The soles are made of a sticky rubber compound. A helmet should be worn to prevent fatal injuries in t

The following are guidelines that every climber should follow to avoid injury:

Always climb with a professional instructor or experienced climber.

Always wear a harness and helmet that fit properly.

Follow instructions on your gear and make sure that they are in great condition.

Only use a harness for under two years. The more you fall, the more worn out the harness will be. Be aware of damage to it.

After you fall, replace your ropes. Or if there is any damage to the rope.

Only use climbing ropes for climbing.

Lower risk of injury by stretching regularly and doing exercises.

Drink water before exercising to avoid dehydration and putting your body at risk of injury.

4.3.2 Acute Mountain Sickness

Acute mountain sickness usually happens when individuals are exposed to an altitude over 7,000 feet, who haven't adjusted themselves to the altitude before engaging in physical activities. Mountain climbers are among the group of the most at risk. Acute mountain sickness is caused by a lack of oxygen at high elevations. Each individual can tolerate this differently. Symptoms appear a few hours after being exposed and usually if you are in poor physical condition, you are most susceptible. At first headache, fatigue, nausea, poor appetite and breathlessness occur. The most frequent report is loss of sleep. In severe cases, an individual's judgment may become altered, and also pulmonary edema can result. This is caused when fluid builds up in the lungs. Symptoms can be

minimized by ascending less than 500 meters/day to give your body a chance to get used to the altitude change. A prescription known as Diamox is taken before an ascent to lessen the effects. It is a mild diuretic and changes the body's acid-base balance, which stimulates breathing. Symptoms usually go away after a few days, but in severe cases oxygen must be given to the person to help with breathing.

4.3.4 Case Study: Rock Climbing

In 2000, a study was done by the Official Journal of the American college of Sports Medicine, on overuse injuries on rock climbers. The purpose of this study was to examine an elite group of rock climbers for the prevalence of pulley rupture and report of injuries that commonly occurred in their hands and elbows. The study was conducted on 42 advanced rock climbers competing in the U.S. national championships. They were evaluated by an injury survey and by the same exams done by the same examiner. Pathology was tested for bowstringing at the PIP joint and proximal phalanx, PIP collateral ligament laxity and tenderness, competence of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) tendons, loss of active PIP extension, flexor tendon nodules, and triggering. If the patients history implied carpal tunnel syndrome, epicondylitis, or chronic shoulder pain, examination was done. [65]

The data was analyzed in a number of variables including age, gender, total years of climbing, top difficulty level, and years of climbing at an elite level. Of the forty-two climbers that took part in the study, the mean age was about 25 years old. (Range 13-40). There were 35 male climbers and 7 female. The mean difficulty level

[65] Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Pg.1369-1372

was Expert (Range beginner, intermediate, advanced, expert). All climbers were at an elite level.[66]

The total number of injuries were 126. Of these 76 (63%) were in the hand, and 46 (37%) were in the upper extremity. Out of the 46 climbers, only one didn't report an injury. The injuries are summarized in Table 9. Results showed that there was no association between the number of injuries and the climbers' ages, or their ability levels.

[66] Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Pg.1369-1372

Table 9: Upper Extremity Injuries in Rock Climbing (Prevalence in Parenthesis)[67]

Injury	Number of Injuries Recorded (% of Injuries)
Collateral ligament injury	17 (40.5)
Shoulder pain	14(33.3)
Bowstringing	11(26.2)
Flexor unit strain	11(26.2)
A2 pulley pain	10(23.8)
Tendon nodule	10(23.8)
Medial epicondylitis	9(21.4)
Lateral epicondylitis	4(9.5)
Musculotendon junctional pain	3(7.1)
Wrist undercling injury	3(7.1)
Carpal Tunnel syndrome	3(7.1)

[67] Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Pg.1369-1372

CHAPTER V: The Occurrence of Injuries in the Workplace

5 Introduction

Similar to sports, the workplace is accompanied with underlying dangers. Some may argue that only specific environments come with such perilous threats, however, statistics show that injury can occur in any type of working environment. The industrial setting where much heavy lifting is required has its obvious dangers. The office, though, is where much of the danger lies. The repetition of small movements, or lack of movement, can also lead to serious injuries. This chapter goes further to discuss the threats and dangers of the workplace and some possibilities of how they can be solved.

The Bureau of Federal Labor Statistics in 2004 reported 5,701 fatal work injuries recorded in the United States. For 2004, the rate of fatal injuries was 4.1 to every 100,000 employees. This percent had increased 2% since 2003.[68]

From 2003 to 2004 twenty-seven States reported a higher number of fatal injuries. Alaska, Connecticut, Florida, Louisiana, New Jersey, and New Mexico all reported an increase of at least 20 percent of injuries resulting in death, while Arkansas and Oregon reported a declination of 20 percent.[69]

The study found that workers over the age of 55 increased 10 percent and workers between the ages of 16-24 had decreased. 12 percent of fatal injuries were due to a

[68] "National Census of Fatal Occupational Injuries in 2004." Pg. 1
[69] "National Census of Fatal Occupational Injuries in 2004." Pg.1

worker being hit by an object, 17 percent were caused by falling off a ladder or roof, and 8 percent were due to work in construction.[70]

Non-fatal and fatal injuries in the United States in all work industries are shown in Appendix B.

5.1 Back Injuries in the Workplace

Back injuries are the most common and costly work related injuries. Lower back pain affects about 1,000,000 workers in the United States every year. This results in the most days of work missed due to musculoskeletal disorders. Of all injuries reported, back injuries account for 20% of all injuries and illnesses in the workplace. This costs the nation about 20 to 50 billion dollars every year.[71]

In 1998, more than 440,000 people missed work at least once due to back injuries. This accounted for one-quarter of all nonfatal injuries that caused people to miss work. People with back injuries on average miss six working days. About 20% of people with back injuries miss more than 31 days of work every year.[72]

Companies have increased costs associated with back injuries. Many companies implement safety measures, and have ergonomics programs. The use of Back belts has also become more popular. However, neither of these have had a great impact. Most back injuries occur when a person is required to lift heavy objects that cause them to use awkward posture. About 25% of work-related back pain is a result of overexertion.[73]

People who have jobs where they stand continuously, or have poor posture when sitting for long periods of time experience a high risk of low-back pain. Acute lower

[70] "National Census of Fatal Occupational Injuries in 2004."Pg. 1
[71] "Back Injuries in the Workplace." University of Minnesota. Pg. 1
[72]" Back Injuries-Nation's Number One Workplace Safety Problem." Pg. 1
[73] "Back Injuries-Nation's Number One Workplace Safety Problem." Pg. 1

back pain is reported to affect 60% of people with lower back injury. Disc-herniation and spinal stenosis are other common injuries. Whole-body vibrations can cause lower back pain in workers that drive trucks, cars, or industrial vehicles.[74]

Lower-back disorders are accountable for 30% of injuries that result in a person taking time away from work. Lost productivity, heath-care related expenses, and disability are all affected due to this. Compensation claims for workers with lower back pain are a cost of about $8,500. The average injury claim is about $4,500, per year; and results in $50 to $100 billion in total cost.[75]

[74] "Back Injuries-Nation's Number One Workplace Safety Problem." Pg. 1
[75] "Back Injuries-Nation's Number One Workplace Safety Problem." Pg 1

5.2 Prevention of Back Injuries

Some ways to reduce the amount of injuries is to train employees to utilize lifting techniques that place minimum stress on the lower back, physical conditioning or stretching programs to help reduce risk of muscle strain, and the use of back belts.

There is much debate on whether back belts can actually prevent injuries. Back belts are sold under the assumption that they can reduce risks of back injuries; however there isn't enough scientific evidence to support this (Figure 31).

Figure 31: Back Belt[76]

The National Institute for Occupation Safety and Health (NIOSH) believes that the best way to prevent lower back injuries is to implement ergonomics programs. Ergonomics programs redesign the work environment and work tasks. This can reduce the hazards of lifting heavy materials. This involves controlling the engineering of the object to be lifted and the engineering of the work environment. This can be controlled by having a reduction in the size or weight of the object that requires lifting, adjusting the

[76] "Ergonomic Products-Back Belts." Linden Safety Supply Co. Pg.1

height of the shelf or pallet that it needs to be placed on, installing mechanical aids such as pneumatic lifts, conveyors, and automated materials handling equipment. Other factors that should be taken into consideration are the frequency of the lifting action, duration of lifting activities, the type of lifting, the age, sex, body size, state of health, and the general physical fitness of the individual.

In order to use ergonomic programs, jobs must be evaluated. Jobs that use frequent bending, lifting, twisting, pushing, or pulling must be redesigned. When lifting heavy loads, they should be placed closer to the body and between shoulder and knuckle height. Twisting jobs should be totally eliminated. Implementing slides, chutes, hoists, and hand trucks to move larger loads is a necessity.

Proper lifting techniques are necessary to avoid injury to the back. Figure 32 and Figure 33 demonstrate improper and proper ways to lift an object. When an object is lifted off the floor, you shouldn't lift from a standing position. You need to kneel down, resting one of your knees on the ground and lift the object from your legs and hold it close to your body. Your legs should do all of the work.

Figure 32: Wrong Way to Lift Objects[77]

Figure 33: Correct Way to Lift Objects[78]

Alternative ways to lift items include using a hand truck, shown in Figure 34. A hand truck is used mainly by beverage companies and the United States Postal Service. This allows for an easier transport of boxes or beverage containers.

[77] "Back Safety and Lifting Techniques." Pg.1
[78] "Proper Lifting Techniques." U.S. Navy. Pg.1

Figure 34: Hand Truck[79]

The use of a hand trucks may pose another problem for workers who must use the device on uneven surfaces, up and over curbs and stairways. Curb ramps are an easy solution to eliminate the need to lift or pull them especially with fully loaded hand trucks.

Figure 35: Curb Ramp[80]

Other ways to lift heavy items include a solo lift as shown in Figure 36. The Solo Lift is clamped to the outside of the box by small spikes that are pressed into it. This causes no damage to the box. The boxes can be lifted with one hand and allow the worker to carry them at the side of their body.

[79] "U.S. Consumer Product Safety Commission." Pg. 1
[80] "Hand Trucks." U.S. Department of Labor. Pg. 1

Figure 36: Solo Lift[81]

Vacuum lifting is another technique to eliminate strains on the back and body (See Figure 37). It mainly consists of a vacuum mechanism which transfers air pressure through a tube. These tubes lead to suction cups which can be placed in any orientation to obtain on optimal lift without damaging the product. This sort of lifting may require a human to guide the merchandise, however, the vertical lift, which is usually the culprit of back injuries, is eliminated.

Figure 37: Vacuum Lifting[82]

[81] "Help with Lifting Heavy Boxes." Agency for International Business and Cooperation. Pg.1
[82] "Ergonomic Vacuum Tube Lifter." Pg. 1

The Automatic 2-Box Grab demonstrated in Figure 38 is a mechanism that introduces another alternative to lift boxes without human strain. This has an advantage over the vacuum system because it can lift two larger boxes at once. It also does not require the additional power of a vacuum since it is done mechanically.

Figure 38: Automatic 2-Box Grab[83]

[83] "Automatic 2-Box Grab." Bradley Lifting Corporation. Pg. 1

5.3 Hand Injuries in the Office

Injuries to the hand are primarily a result of overuse and repetitive motions, such as keyboard typing, the use of a computer mouse, also recurring motions such as twisting, turning, and grasping. Without treatment, overuse injuries can become extremely painful because they will progressively worsen. Lack of treatment will result in loss of strength and flexibility, pain, numbness, and tingly sensations. Areas that are most affected by this are the hands, fingers, wrists, elbows, shoulders, and backs.

Tendonitis and Carpal Tunnel Syndrome are some of the most common injuries to the hand as a result of repetitive motion. Tendonitis is the inflammation of muscles that results in impairment of the normal gliding of the muscle, as shown in Figure 39.

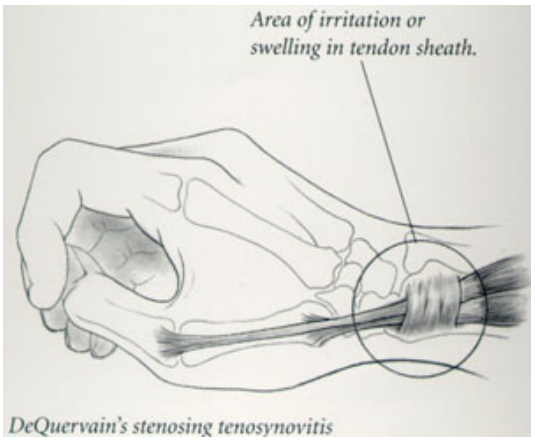


Figure 39: Tendonitis in the Hand[84]

[84] "Common Hand Problems." American Academy of Orthopedic Surgeons. Pg. 1

Workers who are at risk to develop Tendonitis and Carpal Tunnel Syndrome include:

- Graphic Designers from typing and using the computer mouse
- Computer Illustrators
- Programmers
- Other computer users
- Musicians
- Dental Hygienists
- Cashiers

These workers are at risk because their jobs require them to endure long periods of steady hand movement doing the same tasks over and over, holding positions for extended periods of time, working in awkward positions, making forceful movements, and not taking breaks in between the repetitive tasks.

5.4 Prevention of Hand Injuries in the Office

Overuse injuries in the workplace can be prevented by proper setup of the work area and knowing when your body feels uncomfortable. Adjustments should be made and ergonomic programs used to set up workstations.

While working at a computer, the worker should take frequent breaks from the computer preferably for every hour of computer use, a 10-15 minute break is suggested. As soon as the worker feels stress or strains on their hands, they should stop what they are doing and try to complete a series of stretches that are shown in Figure 40, to relax the hand and wrist.

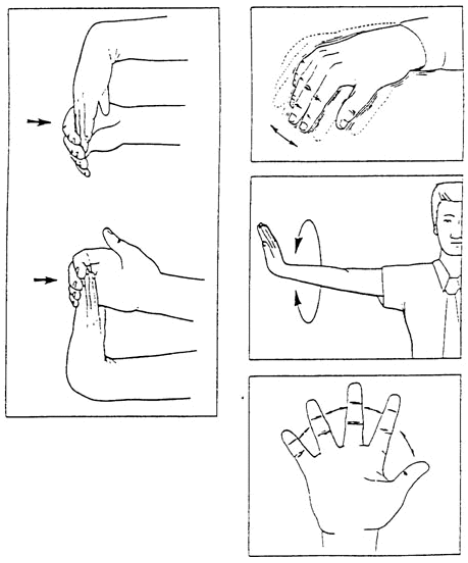
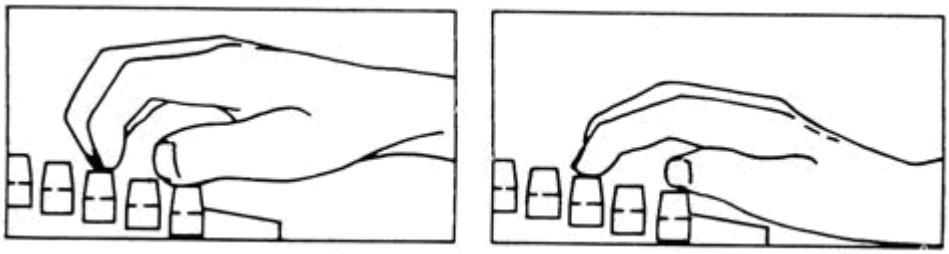


Figure 40: Shoulder, arm, and hand stretches[85]

Proper set-up of the computer should include adjusting the monitor so that the screen is eye level. The screen should be 1.5-2 feet away from your eyes. This will involve less motion and twisting on your neck. The keyboard shouldn't be attached to the monitor. It should lay on a stand and be parallel with the floor. The height should be adjusted so that the workers elbows are at their side, wrists in a neutral position, and their arms parallel to the floor.



a) **b)**

Figure 41: Figure a) Correct positioning of wrist while typing, Figure b) incorrect positioning[86]

[85] Ubelacker, Sandra. "RSI." Pg. 1
[86] "Computer Ergonomics on Human Posture." Pg. 1

The mouse should be located closely to the edge of the desk to prevent extending the arm. The mouse should be at the same level that the keyboard is. The worker should hold the mouse in a straight, level position avoiding positioning their wrist upward, downward, or left and right, as shown in Figure 42.

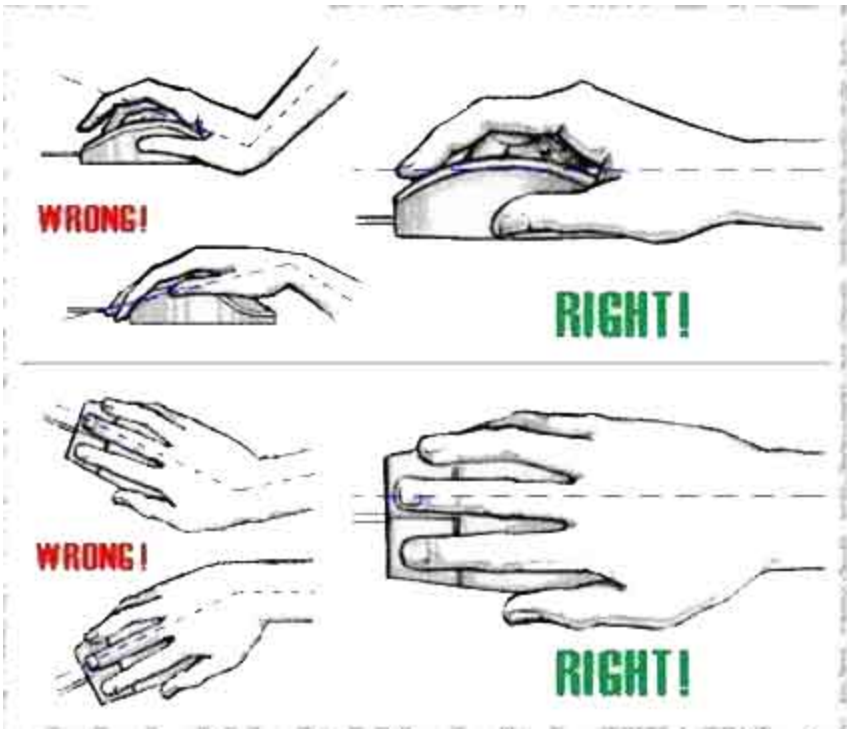


Figure 42: The left column shows the wrong way to position your hand on the mouse; the right column shows the correct position of the hand in a level, neutral position.

Another alternative to maintaining the correct position of the wrist and hand is to incorporate a mouse wrist pad and a keyboard gel pad into the workplace.

a)

b)

Figure 43: Figure a) Mouse Pad Figure b) Keyboard Gel Pad[87]

5.5 Hand Injuries in the Workplace

Hand injuries result in ¼ of all injuries that result in days away from work. Most injuries to the hand are unreported due to the fact that they are considered not as serious as other injuries. Figure 44 represents the percent of injuries in the workplace occurring at different parts of the body. According to the National Safety Council, hand injuries cost about $4,200 per year. [88]

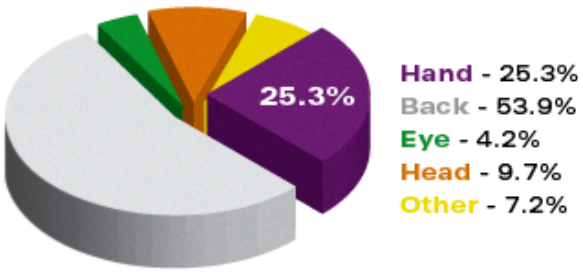


Figure 44: Pie Chart Comparing Injuries in the Workplace[89]

OSHA requires that employees must use the proper hand protection when they are exposed to harmful substances, cuts or lacerations, abrasions, punctures, chemical burns, thermal burns, harmful temperature extremes, and sharp objects. Of the workers who

[87] Haselkorn, Alexander. "Proper Posture/Ergonomics." Pg. 1
[88] "Preventing Hand Injuries." Pg. 1
[89] "Preventing Hand Injuries." Pg. 1

suffered hand injuries, 70% were due because safety gloves were not worn, and 30% were due to workers not wearing their gloves correctly, or wearing damaged gloves. [90] [91]

Different gloves are used for different purposes. Workers need to use the appropriate gloves while performing certain tasks. Gloves are designed for many reasons, including the following: cut resistant gloves, chemical resistant gloves, heat resistant gloves, gloves that endure a long duration of contact, gloves designed for certain grip requirements, gloves to protect the hand as well as the forearm, and gloves for police, fire, and Emergency Medical Service (EMS).

5.5.1 Cut Resistant Gloves and Chemical Resistant Gloves

Cut resistant gloves are used for many occupations. They are used to protect against knives, sharp objects, metal parts, and glass. Hand injuries could be prevented by the use of gloves. Some occupations that should use cut resistant gloves include meat and poultry workers and contractors; so as to prevent against puncture and cuts from sharp objects. Also included are Armed Forces who use gloves to handle barbed wire and razor wire. Examples of these types of gloves are shown in Figure 45.

Figure A) **Figure B)**

Figure 45: Figure A) Stainless Steel Leather Glove Figure B) Chain Mail Glove[92]

[90] "Preventing Hand Injuries." Pg. 1
[91] "Hand Protection." 2005. Nonprofit Risk Management Center. Pg. 1

Gloves are used to prevent against three types of cuts. These are abrasive cuts, slicing cuts, and impacting cuts. Abrasive cuts are caused when the type of glove you wear rubs up against the parts that you handle. This commonly occurs when handling plastic parts or sheet metal. Slicing cuts are caused by sharp edges. Workers who work with knives are highly at risk and also the food handling industry. Impact cuts are a result of a person being struck by a piece of glass or metal that has fallen or is being projected. This type of injury usually affects the thumb.

There are different types of materials that gloves are made of that are used to protect against chemical substances. These include:

1. Natural Rubber
2. Synthetic Rubber
   Chloroprene (Neoprene), Nitrile rubber
3. Plastics
   Polyurethane, Polyvinyl alcohol (PVA), Polyvinyl chloride

Permeation and degradation resistance guides for chemical resistant gloves are shown in Appendix A.

[92] "Work Gloves: Cut Resistance." Pg. 1

Natural Rubber Gloves that use natural rubber are very high in elasticity. This results in less tear than normal gloves. Than can handle temperature between 18-149°C. However is has very little resistance to flames. It can protect against water, alcohols, and certain ketones.

Chloroprene Gloves resist minor cut and degradation. It is flame resistant and can handle temperatures up to 93°C. These gloves protect against acids, alcohols, fats, caustics, refrigerants, ketones, detergents, and fertilizers.

Nitile Rubber Gloves protect against punctures, cuts, snags, and abrasions. They are not flam-resistant. They can handle temperatures between -4-149°. Nitile Rubber protects against oils, fuels, and some organic solvents.

Polyurethane (PU) Gloves have a high tensile strength. They aren't used for temperatures above 79°. These gloves are primarily used for cleaning and are used as a waterproof liner for other gloves.

Polyvinyl Alcohol (PVA) Gloves protect against punctures, cuts, snags, and abrasions. They resist hydrocarbons, chlorinated solvents, esters, and some ketones. They do not resist water, acids and bases, and light alcohols.

Polyvinyl Chloride (PVC) Gloves protect against abrasions, but not cuts or punctures. The gloves should be worn in temperatures less than 82°C. It protects against water and most aqueous solutions, detergents, and diluted acids and bases. [93]

5.5.2 Case Study of Hand Injury in the Workplace

Studies show that people put themselves at more risk of injury in the workplace due to mental and physical fatigue. In a study conducted by the National Institute for Occupational Safety and Health, 1,128 patients were used in a study of hand injuries occurring in the workplace. Patients participated over a two year period from 24 health clinics in New England. The factors that were tested were, the time of day that the injury

[93] "Preventing Hand Injuries." Pg. 1

happened, the time the shift started, if the person was working overtime, and the hours of sleep before the injury occurred. [94]

The data showed that 77.5% of males about 36 years old had had the most injuries. About 43.2% of the hand injuries were recorded to have happened between 9:00 – 12:00 am. The injuries generally occurred 3.5 hours into the persons work shift. Of the injuries, only 4% happened while working overtime. The difference of sleep was between 1 – 0 hours. The study concludes that hand injuries show a trend of happening early in the workday. The amount of sleep wasn't a key factor in the risk of injury. [95]

5.5 Knee Injuries in the Workplace

Knee injuries are as common in the workplace as they are in sports. Injuries common to the knee in sports are also familiar to the workplace. ACL injuries and meniscal injuries rank among the most frequent in the workplace. This fact, however, should not be surprising when considering the perils that exist in the workplace which may be similar to those seen in on a sports field. Surprisingly, these major injuries are not the only dangers that exist for the knee in the workplace. There are also injuries that are commonly seen to other body parts in the workplace that occur, namely cumulative trauma disorders (CTD) or repetitive stress injuries (RSI).

[94] Lombardi, D A., G S. Sorock, E A. Eisen, R F. Herrick, R B. Hauser, R Racine, and M A. Mittleman. "Temporal Factors and the Risk of Occupational Acute Hand Injury." Pg. 1
[95] Lombardi, D A., G S. Sorock, E A. Eisen, R F. Herrick, R B. Hauser, R Racine, and M A. Mittleman. "Temporal Factors and the Rish of Occupational Acute Hand Injury." Pg. 1

Any and all of these injuries can disable a person for any period of time. Some injuries recur and can result in a loss of substantial working time. Those injuries that occur once in a period of 4 weeks can be dubbed acute, which would not be incredibly detrimental to an employees performance. However, sub acute and chronic injuries, or those that recur in a period of 1-3 months or longer than 3 months, respectively, can keep an employee out of work for countless amounts of time.

The workplace can require employees to exert themselves physically a number of times within a day. If this physical exertion requires lifting of any sort, proper techniques must be implemented to reduce the risk of injury. During lifts, keeping the back safe requires putting the knees at risk. To keep the stress off the back, a worker will lower themselves closer to the ground, requiring the knees to be stressed more heavily at the peak of the range of motion. At this point, or any time during the lift, the knee is a potential point of injury. A simple twisting motion which may feel normal at first, may tear an ACL, or injure the meniscus. In an ACL injury the worker will feel great amounts of pain which will persist for up to 8 weeks, and possibly for his/her entire life. A meniscus injury may not yield as much pain at first, but the damage is still comparable. An injured meniscus raises the stresses on the knee up to 230%. The types of situations which introduce these risks are evident in a number of professions. Of course there are the obvious physical laborer jobs which produce these sorts of heavy lifting environments. However, professions in the office may have the same perils lying in close proximity. [96]

The previous injuries can happen in the blink of an eye, and have you out of a job for weeks or months. But, what should not be overlooked are CTD's and RSI's, which

[96] Feinberg, Steven D. "The Knee: Meniscal Injuries and Treatment." Pg.1

develop over long periods of time. For instance, jobs that require a repetition rate for the hands which exceeds 1,500 per hour are known to cause inflammation in tendon sheaths. This may first go undetected (to the eye on physical sensation), but once the damage has been done these injuries can be even harder to recover from than those earlier stated.[97]

A CTD that exists in the knee affects the Iliotibial band, known as iliotibial band syndrome (ITBS). The iliotibial band is a tendonlike band that stretches from the illium to the tibial head. Overuse of the knee sometimes inflames the band which may keep a worker from being active. Although inflammation may reduce, and the worker will probably return to work, the band will most probably be tight and will most likely become inflamed again. This is typically what happens with ITBS, and can be quite debilitating for long periods of time for many people.

Figure 46: Iliotibial Band[98]

[97] Ergonomics." Oregon OSHA. Pg. 1
[98] "Runners Knee (Inflammation of the Illiotibial band-ITB)." Pg. 1

5.6 Knee Injury Prevention

Knee injury prevention and rehabilitation can be taken care of in the form of a knee brace. There are three different classifications of knee braces: prophylactic, functional, and petellofemoral. Each classification serves a different level of protection to the knee and its constituents.

A prophylactic brace will help rehabilitate or prevent MCL and ACL injuries (Figure 47). It can help absorb valgus stresses applied to the MCL and any rotational stresses to the ACL. Prophylactics are utilized in professional sports leagues such as the NFL. Players have reported mixed feelings about them. "Skill Players", or runners and receivers, sometime complain that prophylactic braces limit the speed and range of flexibility. However, linemen at risk for MCL injuries often wear prophylactics since the demand for speed of their knee joints is far less than a skill player.

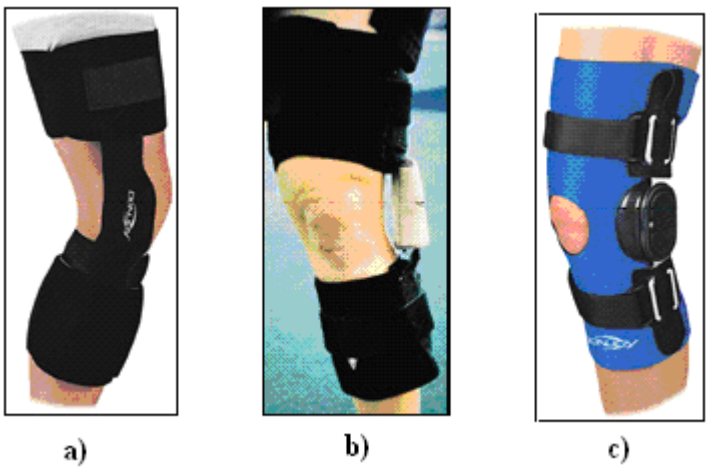


Figure 47: Prophylactic Knee Braces[99]

Functional knee braces made a large impact after Joe Namath's return to the NFL after a crippling knee injury in which his functional knee brace helped him return to his old form (Figure 48). The functional brace is designed to reduce the stresses applied to the ACL in quick changes of direction. It does not protect the MCL unlike the protection capabilities of the prophylactic brace. Some drawbacks found with the functional knee brace are the increase in muscle energy expenditure, and contact injuries with others, which doesn't pose a threat highly in the workplace.

[99] Kim, Soo M., Scott Horowitz, Jin H. Lee, and Cathy Hong. "Biomechanics of the Knee." Pg. 1

Figure 48: Functional Knee Braces[100]

The three previously examined braces are all different ways to help prevent and rehabilitate knee injuries sustained in any environment. They do meet their purpose, but do not eliminate recovery time, or the pain associated with the injury. The best prevention for knee injuries in the workplace, is knowing where and when the injuries can occur, and avoiding those situations.

[100] Kim, Soo M., Scott Horowitz, Jin H. Lee, and Cathy Hong. "Biomechanics of the Knee." Pg. 1

CHAPTER VI: Conclusion

The risk of injury is always an imminent threat in day to day life, mostly to those engaging in some sort of physical activity. Both sports and activities in the workplace have been put under our scope and it is evident that injuries are a threat worth analyzing. In both environments the potential for injury is presented by the bounds of the activity and to eliminate them would eradicate the activities altogether. However, knowing the environments that harvest them grants us the power to minimize them. Factors of speed and added weight intensify sustained injuries by an incredible factor.

Research and analysis has identified various causes of injury in three high velocity sports, and the workplace. Mountain biking, rock climbing and alpine skiing all present dangerous and threatening circumstances to our physical being especially where speed is concerned. The workplace presents workers with numerous types of risks, especially where lifting objects is concerned. Since, in neither case can the source of the risk can be eliminated, alternative measures must ensue to make a favorable impact. With the understanding of these circumstances and risk areas, and engineering data gathering and analysis, many conclusions can be made on reducing our risk of injury.

Therefore, this report stands as a foundation for those who choose to minimize the frequency and severity of injuries in sports and the workplace. In addition, it also arouses thoughts of not only ways to prevent injury, but also spawns the beginning of perhaps new sport injury prevention or workplace safety focus groups.

Bibliography

1. "ACL Knee Surgery Explained." 2001. Medical Internet Solutions. 10 May 2005 <http://www.aclsolutions.com/surgery_5.php>.

2. Acquaviva, John. "Rock Climbing." June 2005. Roanoke College. 12 Mar. 2005 <http://www.healthatoz.com/healthatoz/Atoz/hl/fit/spor/rockclimbing.jsp>.

3. "Anatomy of the Back." Northern California Neurosurgery Medical Group, Inc. 17 Nov. 2005. 11 Dec. 2005 <http://www.lieberson.com/en/neuro_medical_info/spinal_anatomy.htm>.

4. "Arthroscopy of the Knee." 2004. Nucleus Medical Art. 2 May 2005 <http://www.ehealthmd.com/library/arthroscopyknee/ARK_whatis.html>.

5. "Automatic 2-Box Grab." Bradley Lifting Corporation. 12 Oct. 2005 <http://www.bradleylift.com/gallery/details.php?id=427>.

6. "Back Injuries in the Workplace." University of Minnesota. 20 Oct. 2005 <http://enhs.umn.edu/2004injuryprevent/back/backinjury.html>.

7. "Back Injuries-Nation's Number One Workplace Safety Problem." 1993. U.S. Department of Labor. 22 Oct. 2005 <http://www.osha.gov>.

8. "Back Safety and Lifting Techniques." 25 Oct. 2005 <http://northonline.northseattle.edu/backcare/techniques>.

9. Barnas, Gary P. "Altitude Sickness." 2004. Medical College of Wisconsin. 10 May 2005 <http://healthlink.mcw.edu/article/907195877.html>.

10. "Bones of the Hand." Encarta. 2005. 05 Oct. 2005 <http://encarta.msn.com/media_461566262/Bones_of_the_Hand.html>.

11. "Carpal Tunnel Syndrome." 2003. American Academy of Family Physicians. 18 May 2005 <http://www.aafp.org/afp/ 20030715/279ph.html>.

12. "Chemical Resistance Guide." 2005. 20 Oct. 2005 < http://www.superiorglove.com/documents/products/346/CHEM_GUIDEv2.pdf >.Johnson, Robert J., Paolo Zucco, and Jasper E. Shealy. Skiing Trauma and Safety. 1st ed. Vol. 13. West Coshohocken, 2000.

13. "Common Hand Problems." American Academy of Orthopedic Surgeons. 16 Oct. 2005 <http://orthoinfor.aaos.org/brouchure/thr_report.cfm?Thread_ID=8&topcategory=Hand>.

14. "Computer Ergonomics on Human Posture." 2001. 16 Oct. 2005 <http://filipinovegetarianrecipe.com/health_complication/computer_ergonomics_on_human_posture.htm>.

15. "Ergonomics." Oregon OSHA. 1 Nov. 2005 <http://www.cbs.state.or.us/external/osha/educate/training/pages/201disorders.html>.

16. "Ergonomic Products-Back Belts." Linden Safety Supply Co. 24 Oct. 2005 <http://lindensafety.com/details.cfm?id=149>.

17. "Ergonomic Vacuum Tube Lifter." 12 Oct. 2005 <http://www.expo21xx.com/fluid21xx/8400_st2_vacuum-pump/default.htm>.

18. Feinberg, Steven D. "The Knee: Meniscal Injuries and Treatment." 2000. Magazine for the Workplace Community. 30 Oct. 2005 <http://www.cwce.com/feinbergarticles/meniscustrans.htm>.

19. Fevžer, Aleš. "Cycling Races." Information about Slovenia and its Government. 1997. Government Public Relations And Media Office. 08 Oct. 2005 <http://www.uvi.si/eng/slovenia/photos/recreation-sport/080/index.text.html>.

20. Frobose I, Lucker B, Wittmann K. "Overuse symptoms in mountain bikers: a study with an empirical questionnaire." Dtsh Z Sportmed 2001; 52 (11): 311-5

21. Giunti Editorial Group, Atlas of Anatomy. 3rd ed. Florence: Giunti Editorial Group, 2002. 5-240.

22. Gundel, Md, Jeff. "Common Alpine Skiing Injuries." 2001. Adirondack: Sports & Fitness. 4 Apr. 2005 <http://www.adksportsfitness.com/back_issues/december2000/articles/alpine_injuries.html>.

23. "Hand Protection." 2005. Nonprofit Risk Management Center. 16 Oct. 2005 <http://www.nonprofitrish.org/ws-ps/topics/PPE/hand-ps.htm>.

24. "Hand Trucks." U.S. Department of Labor. 12 Oct. 2005 <http://osha.gov/../beverage/hand_trucks.html>.

25. Haselkorn, Alexander. "Proper Posture/Ergonomics." 2001. 16 Oct. 2005 <http://www.wristhand.com/ergonomics.html>.

26. "Help with Lifting Heavy Boxes." Agency for International Business and Cooperation. 12 Oct. 2005 <http://hollandtrade.com/vko/zoeken/ShowBouwsteen_NewProducts.asp?bstnum=574>.

27. "High Velocity Injuries." University of Utah: Wilderness Medicine. 17 Mar. 2003. 4 May 2005 <http://www-medlib.med.utah.edu/WildernessMedicine/subman_ch3.htm>.

28. Hill, Lindsay, Tom Sutton, and Joan McIntosh. "Bike Sense." Greater Victoria Cycling Coalition. 2003. 2 May 2005 <http://bikesense.bc.ca/ch2.htm>.

29. Huston, Craig, B.S.E., Brandser, Eric, M.D. "Right Knee: Medial View." Virtual Hospital. 1992. 05 Oct. 2005 <http://www.vh.org/adult/provider/radiology/JointFluoro/Knee/knee.lat.13.html>.

30. Jebson, Md, Peter L., and Curtis M. Steyers, Md. "Hand Injuries in Rock Climbing: Reaching the Right Treatment." The Physician and Sports Medicine os 25 (1997). 22 Apr. 2005 <http://www.physsportsmed.com/issues/1997/05may/jebson.htm>.

31. Kim, Soo M., Scott Horowitz, Jin H. Lee, and Cathy Hong. "Biomechanics of the Knee." 2003. 25 Nov. 2005 <http://robots.rutgers.edu/course/Projects/dms/background.html>.

32. Kronisch, M.d., Robert L. "How to Fit a Mountain Bike." The Physician and Sports Medicine os 26 (1998). 22 Mar. 2005 <http://www.physsportsmed.com/issues/1998/03mar/kronpa.htm>.

33. Langran, Dr, Mike. "Knee Injuries." 2005. 2 May 2005 <http://www.ski-injury.com>.

34. Levy, Allen M, Fuerst, Mark L. "Top 10 Sports Injuries." Sports Injury Handbook. 2002. 10 Oct. 2005 <http://www.sportsinjuryhandbook.com/injuries/index.html>.

35. Lombardi, D A., G S. Sorock, E A. Eisen, R F. Herrick, R B. Hauser, R Racine, and M A. Mittleman. "Temporal Factors and the Risk of Occupational Acute Hand Injury." 2001. NIOSH. 23 Oct. 2005 <http://www.cdc.gov/niosh/noirs/abstractsc3.html>.

36. Marxhausen, Paul. "Computer Related Repetitive Strain Injury." 2005. 22 Oct. 2005 <http://eeshop.unl.edu/rsi.html>.

37. Matsumoto, Kazu, Miyamoto Kei, Sumi Hiroshi, Sumi Yasuhiko, and Shimizu Katsuji. "Upper Extremity Injuries in Snowboarding and Skiing: A comparative Study." Clinical Journal of Sport Medicine os 12. 2002.

38. "National Census of Fatal Occupational Injuries in 2004." Aug. 2005. Bureau of Labor Statistics. 2 Nov. 2005 <http://www.bls.gov/iif/oshcfoil.htm>.

39. “Neck Pain.” <http://www.chiropractors.com.hk/c12.htm>.

40. Pfeiffer, Ronald P., and Robert L. Kronisch. "Mountain Biking Injuries." Sports Medicine os 32 (2002): 523-535. 1 May 2005 <http://www.ncbi.mlm.nih.gov/entrez/query.fcgi?CMD=Text&DB=pubmed>.

41. "Preventing Hand Injuries." 2005. 17 Oct. 2005 <http://www.superiorglove.com/Stop_Injuries_P481.html>.

42. "Proper Lifting Techniques." U.S. Navy. 25 Oct. 2005 <http://www-nmcp.med.navy.mil/PhysTherapy.backs.asp>.

43. Rehak, David C. "Repetitive Overuse Injuries of the Hand and Wrist." 14 Oct. 2005 <http://www.hughston.com/hha/a.hndwrist.htm>.

44. Rohrbough, Joel T., Kenneth M. Mudge, and Robert C. Schilling. "Overuse Injuries in the Elite Rock Climber." Official Journal of the American College of Sports Medicine os (2000): 1369-1372. Spring 2005 <http://www.msse.org>.

45. "Runners Knee (Inflammation of the Illiotibial band-ITB)." 2005. Sports Injury Clinic. 1 Nov. 2005 <http://www.sportsinjuryclinic.net/cybertherapist/front/knee/irunnersknee.html>.

46. "Shoulder Impingement." American Academy of Orthopaedic Surgeons. 1995. 8 Oct. 2005 <http://orthoinfo.aaos.org/main.cfm>.

47. "Skiing News." 4 Apr. 2005. The Canadian Press. 5 Apr. 2005 <http://http://www.cp.org/english/online/full/skiing/Iskiing.html>.

48. "Skiers Thumb." 11 Sept. 2005 <http://www.orthosports.com.au/hand_skier.html>.

49. "Snow Sports." 2004. Harborview: Injury Prevention and Research Center. 8 May 2005 <http://depts.washington.edu/hiprc/practices/topi/recreation/snowsports.html>.

50. "Tendonitis Information and Treatment Options." 2003. 15 Oct. 2005 <http://www.tendonitis.net/>.

51. Thompson, M.b., Ch.b., Matthew J., and Frederick P. Rivara, M.d.,m.p.h. "Bicycle-Related Injuries." American Academy of Family Physicians os 63 (2001). 2 Mar. 2005 <http://www.aafp.org/afp/20010515/2007.html>.

52. "U.S. Consumer Product Safety Commission." 20 July 2001. 25 Oct. 2005 <http://www.cpsc.gov/cpscpub/prerel/prhtml01/01203>.

53. "Work Gloves: Cut Resistance." 2005. 20 Oct. 2005 <http://www.superiorglove.com/Cut_Resistance_C128.html>.Johnson, Robert J., Paolo Zucco, and Jasper E. Shealy. Skiing Trauma and Safety. 1st ed. Vol. 13. West Coshohocken, 2000.

Appendix A

Understanding The Data

Three categories of data are represented for each product with a corresponding Chemical and Chemical Hazard Code:

1) Degradation Rating 2) Breakthrough Time, 3) Class

DEGRADATION RATING (DR)

- E — Excellent; fluid has little degrading effect.
- G — Good; fluid has minor degrading effect.
- F — Fair; fluid has moderate degrading effect.
- P — Poor; fluid has pronounced degrading effect.
- ▲ — Not Tested
- **NR** — Not Recommended
- **G/E** — A degradation test on this chemical was not run. However, since its break through time is greater than 480 minutes, the Degradation Rating is expected to be GOOD to EXCELLENT.

BREAKTHROUGH TIMES(MINUTES)(BTT)

Class

- 0 — 1 to 10 minutes
- 1 — 11 to 30 minutes
- 2 — 31 to 60 minutes
- 3 — 61 to 120 minutes
- 4 — 121 to 240 minutes
- 5 — 241 to 480 minutes
- 6 — More than 480 minutes

As in EN 374, 1994

CHEMICAL	FB-SERIES/J-SERIES			TORPEDO			CHEMINATOR			NORTH SEA SERIES			CHEMSTOP-FLEX	
	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	BTT	CLASS
Acetone	NR	6	0	NR	11	1	NR	6	0	NR	11	1	11	1
1,2 Dichloro Ethane	NR	4	0	P	11	1	NR	8	0	P	13	1	4	0
1,2 Dichloro Ethane 76% + Phenol 24%	▲	21	1	▲	11	1	▲	14	1	▲	13	1	31	2
1,2-Dichlorethane Reincst	▲	12	1	▲	18	1	▲	8	0	▲	13	1	33	2
1-Butanol	▲	30	1	▲	78	3	▲	80	3	▲	66	3	480	6
2.6-Dimethyl 4-Heptanone	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Acetaldehyde	NR	6	0	P	9	0	P	13	1	P	9	0	18	1
Acetic Acid (Glacial)	F	24	1	G	74	3	G	44	2	G	80	3	252	5
Acetonitrile	▲	12	1	▲	18	1	▲	13	1	▲	16	1	28	1
Acrylamide (50%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ammonium Fluoride (40%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ammonium Hydroxide (30%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Amyl Acetate	▲	16	1	▲	27	1	▲	25	1	▲	29	1	54	2
Aniline	G	65	3	G	83	3	G	90	3	E	145	4	165	4
Battery Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Benzaldehyde	▲	18	1	▲	42	2	▲	40	2	▲	38	2	23	1
Benzene	NR	7	0	NR	15	1	NR	9	0	NR	10	0	5	0
Butoxy Propanol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Butoxy Triglycol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Butyl Acetate	▲	12	1	▲	20	1	▲	12	1	▲	26	1	23	1
Butyl Carbitol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Butyl Cellosolve Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Butyl Dipropasol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6

CHEMICAL	FB-SERIES/J-SERIES			TORPEDO			CHEMINATOR			NORTH SEA SERIES			CHEMSTOP-FLEX	
	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	BTT	CLASS
Butyl Ethylene	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Butyl Propasol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Castor Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Caustic Potash(45%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Caustic Soda (50%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Chlorobenzene	▲	10	0	▲	12	1	▲	14	1	▲	13	1	12	1
Chloroform	▲	4	0	▲	8	0	▲	▲	▲	▲	▲	▲	12	1
Chromic Acid (50%)	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Chromium Trioxide	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Citric Acid (30%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Cooking Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Corn Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Cresol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Cresylic Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Cyclohexane	▲	18	1	▲	38	2	▲	34	2	▲	34	2	480	6
Cyclohexanone	▲	63	3	▲	58	2	▲	49	2	▲	57	2	53	2
Cyclohexanol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Detergent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Di-Butyl Phthalate (D.B.P)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Di-isobutyl Ketone	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Di-isocytl Phthalate (D.I.O.P)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Diacetone Alcohol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dibutyl Phthalate	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Diesel	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethanolamine	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylamine	NR	6	0	▲	7	0	▲	8	0	▲	9	0	▲	▲
Diethyl Ether	NR	4	0	NR	6	0	NR	6	0	NR	5	0	13	1
Diethylene Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylene Glycol Monohexyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylene Glycol Monomethyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylene Glycol Monopropyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dimethylacetamide	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	67	3
Dimetyl Formamide (DMF)	NR	14	1	NR	21	1	NR	22	1	NR	27	1	57	2
Dipropasol Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dipropylene Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylene Glycol Monomethyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Diethylene Glycol Monopropyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dimethylacetamide	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	67	3
Dimetyl Formamide (DMF)	NR	14	1	NR	21	1	NR	22	1	NR	27	1	57	2
Dipropasol Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dipropylene Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Dipropylene Glycol Monopropyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Epoxidised Soya Bean Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	
Ethanolamine	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ethoxytriglycol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ethyl Acetate	NR	6	0	NR	13	1	NR	7	0	NR	13	1	18	1
Ethyl Butanol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ethylene Glycol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Ethylene Glycol Monopropyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Formaldehyde (37%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Formic Acid (90%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Genklene	NR	4	0	▲	8	0	NR	6	0	NR	6	0	5	0
Glycerine	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Ground Nut Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Hexylcarbitol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Hexylcellosolve Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Hydrazine Hydrate (85%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Hydrochloric Acid (10%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Hydrochloric Acid (30%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Hydrochloric Acid (37%)	▲	95	3	▲	▲	▲	▲	210	4	▲	▲	▲	▲	▲
Hydrogen Peroxide	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Hydrogen Peroxide (30%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Hydroquinone	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Iodomethane	▲	5	0	▲	▲	▲	▲	▲	▲	▲	11	1	14	1
Isoamyl Alcohol	F	45	2	G	122	4	G	112	3	F	80	3	480	6
Iso Butyl Alcohol	▲	41	2	▲	91	3	▲	69	3	▲	86	3	480	6
Iso Butyl Methyl Ketone	NR	11	1	NR	22	1	NR	19	1	NR	18	1	32	2
Iso Propyl Alcohol	G	40	2	G	80	3	G	75	3	G	70	3	480	6
Kerosene	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Kerosene (Paraffin)	▲	96	3	NT	119	3	▲	178	4	▲	228	4	▲	▲
Lactic Acid (85%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Malic Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Methoxytriglycol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Methanol	▲	24	1	NT	31	2	▲	▲	▲	▲	▲	▲	480	6
Methyl Acetate	NR	4	0	NR	8	0	NR	9	0	NR	11	1	▲	▲
Methyl Acrylate	NR	3	0	▲	10	0	▲	11	1	▲	11	1	▲	▲
Methyl Alcohol	▲	13	1	▲	20	0	▲	18	1	▲	20	1	67	3
Methyl Ethyl Ketone	NR	4	0	NR	10	1	NR	6	0	NR	10	0	9	0

Methyl Methacrylate	NR	4	0	NR	8	0	NR	9	0	NR	9	0	10	0
Methylcarbitol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Methylene Chloride	NR	4	0	▲	8	0	NR	6	0	NR	6	0	10	0
Milk	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Milk Products	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Monoethanolamine	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Morpholin	▲	26	1	▲	63	3	▲	56	2	▲	38	2	▲	▲
Muriatic Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
N,N Dimethyl Acetamide	▲	14	1	▲	30	1	▲	29	1	▲	34	2	25	1
n-Hexane	NR	8	0	NR	15	1	P	20	1	P	18	1	320	5
n-Ocatnol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Nitric Acid (10%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Nitric Acid (65%)	▲	70	3	▲	245	5	▲	75	3	▲	124	4	480	6
Nitro Benzene	▲	34	2	▲	55	2	▲	43	2	▲	64	3	36	2
Nitro Methane	▲	15	1	▲	16	1	▲	17	1	▲	19	1	▲	▲
Octane (Petrol or Gasoline)	▲	16	1	▲	27	1	▲	36	2	▲	51	2	63	3
Oil-Based Paints	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Oleic Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Olive Oil	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Ortho Phosphoric Acid (85%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Oxalic Acid	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Paraffin (52% Chlorination)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Phenol (76% IN H20)	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	171	4	▲	▲
Pentane	▲	9	0	▲	12	1	▲	19	1	▲	22	1	▲	▲
Petrol	▲	14	1	▲	28	1	▲	24	1	▲	47	2	▲	▲
Perchloric Acid (60%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Phtalic Acid Dibutyl Ester	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Propanol	▲	41	2	▲	82	3	▲	74	3	▲	70	3	▲	▲
Propetamphos (50% IN ROH)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Propoxy Diethylene Glycol	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Propyl Carbitol Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Propyl Cellosolve Solvent	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Propylene Glycol Monobutyl Ether	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Pyridine	NR	10	0	NR	11	0	P	15	1	P	12	1	14	1
Safrotin (50% IN ROH)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Sodium Hydroxide (50%)	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Sodium Hypochlorite (6%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Styrene	▲	12	1	▲	22	1	▲	21	1	▲	24	1	18	1

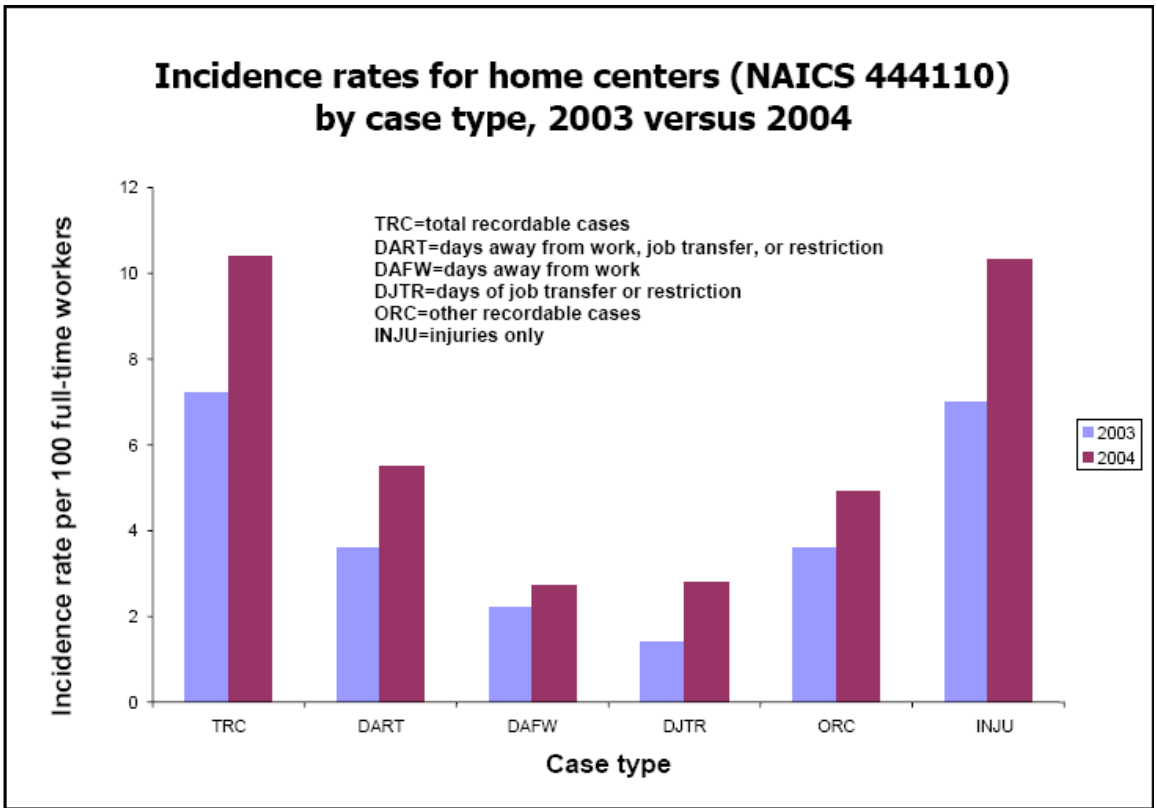
	FB-SERIES/J-SERIES			TORPEDO			CHEMINATOR			NORTH SEA SERIES			CHEMSTOP-FLEX	
CHEMICAL	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	DR	BTT	CLASS	BTT	CLASS
Sulphoric Acid (47%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Sulphuric Acid (Con.)	▲	73	3	▲	104	3	▲	119	3	▲	135	4	87	3
Sulphuric Acid 30%	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Tannic Acid (65%)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Tert- Butyl Amine	▲	72	4	▲	164	4	▲	145	4	▲	150	4	▲	▲
Tetrachloroethylene	P	11	1	P	20	1	P	21	1	P	16	1	36	2
Tetrahydrofuran	▲	8	0	▲	9	0	NR	4	0	▲	14	1	5	0
Toluene	NR	7	1	NR	18	1	NR	11	1	NR	12	1	15	1
Toluene Extra Pure	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	21	1
Trichlorothane	P	14	1	P	15	1	P	17	1	P	15	1	▲	▲
Trichloroethelene	NR	5	1	P	17	1	P	12	1	P	18	1	▲	▲
Tricresyl Phosphate (TCP)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Triethanolamine (TEA)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	480	6
Trixylyl Phosphate (T.X.P)	G/E	480	6	G/E	480	6	G/E	480	6	G/E	480	6	▲	▲
Xylene	NR	20	2	NR	33	2	NR	29	1	NR	24	1	31	2

The results herein are obtained under controlled laboratory conditions and are for guidance only. It is the intention to assist the user to make the correct choice of personal protective equipment. Actual conditions of end use are not simulated and it is the responsibility of the user to determine the risk and make the appropriate choice for protection against such risk. The manufacturer, the distributor and the sales agents accept no responsibility for a user's selection against particular risk. The manufacturer, the distributor and the sales agents do not imply any guarantee or responsibility from information provided that a particular product will suit specific end use.

[101]

[101] "Chemical Resistance Guide." Pg.1

Appendix B


Incidence rates for home centers (NAICS 444110) by case type, 2003 versus 2004
Incidence rate per 100 full-time workers
12
10
8
6
4
2
0
TRC=total recordable cases
DART=days away from work, job transfer, or restriction
DAFW=days away from work
DJTR=days of job transfer or restriction
ORC=other recordable cases
INJU=injuries only
2003
2004
TRC
DART
DAFW
DJTR
ORC
INJU
Case type

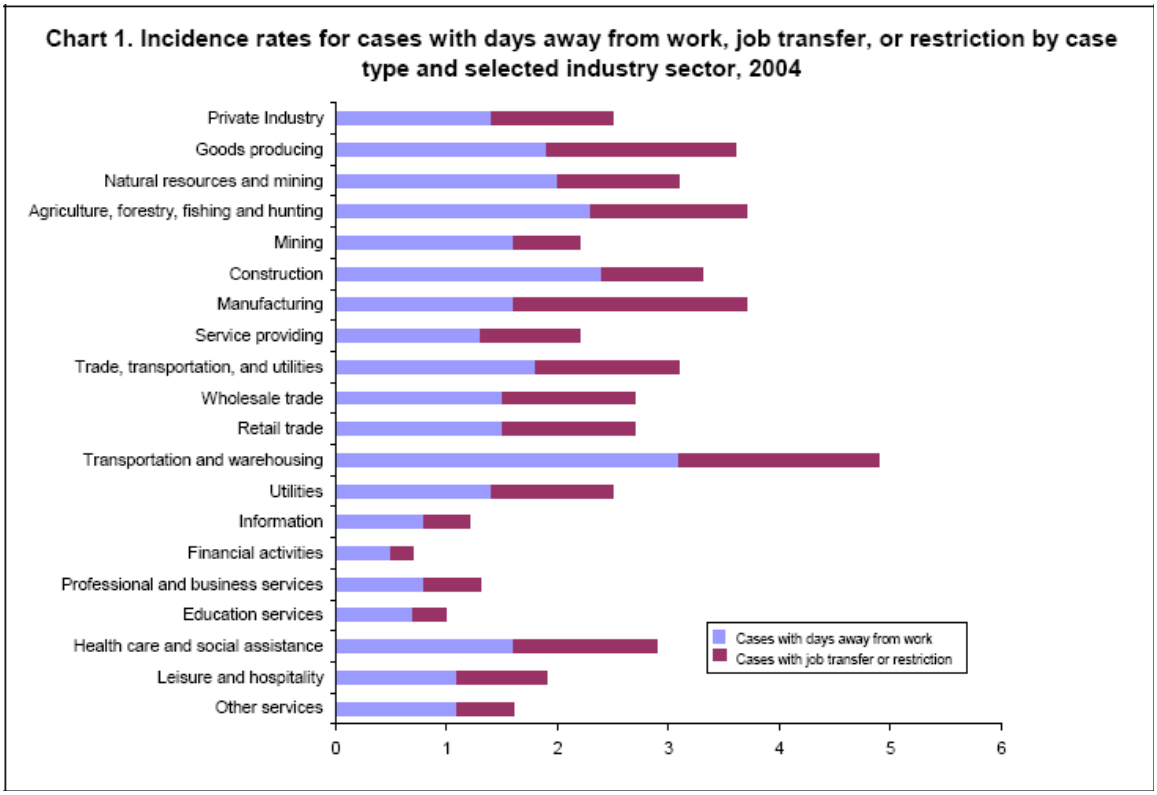


Chart 1. Incidence rates for cases with days away from work, job transfer, or restriction by case type and selected industry sector, 2004
Private Industry
Goods producing
Natural resources and mining
Agriculture, forestry, fishing and hunting
Mining
Construction
Manufacturing
Service providing
Trade, transportation, and utilities
Wholesale trade
Retail trade
Transportation and warehousing
Utilities
Information
Financial activities
Professional and business services
Education services
Health care and social assistance
Leisure and hospitality
Other services
Cases with days away from work
Cases with job transfer or restriction
0
1
2
3
4
5
6

Chart 2. Percent of nonfatal workplace injuries by industry sector, 2004

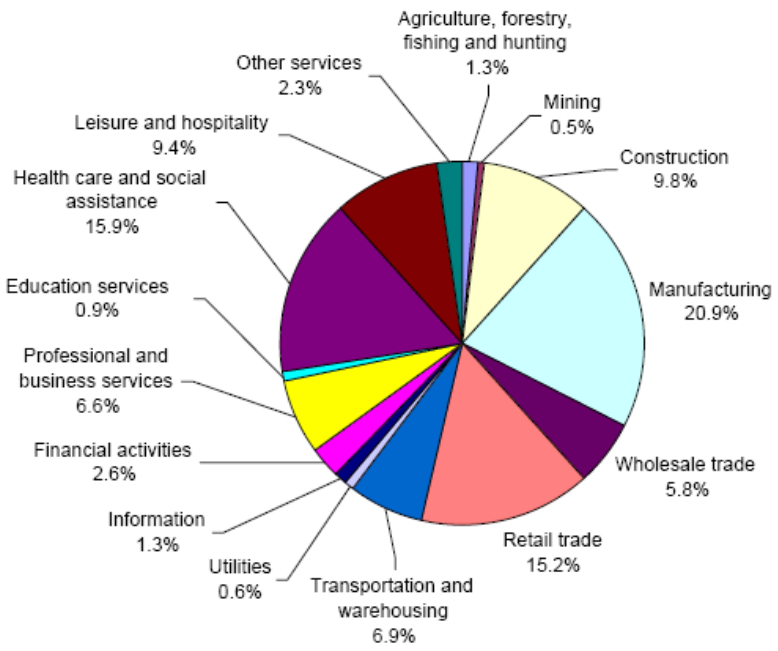


Chart 3. Percent of nonfatal workplace illnesses by industry sector, 2004

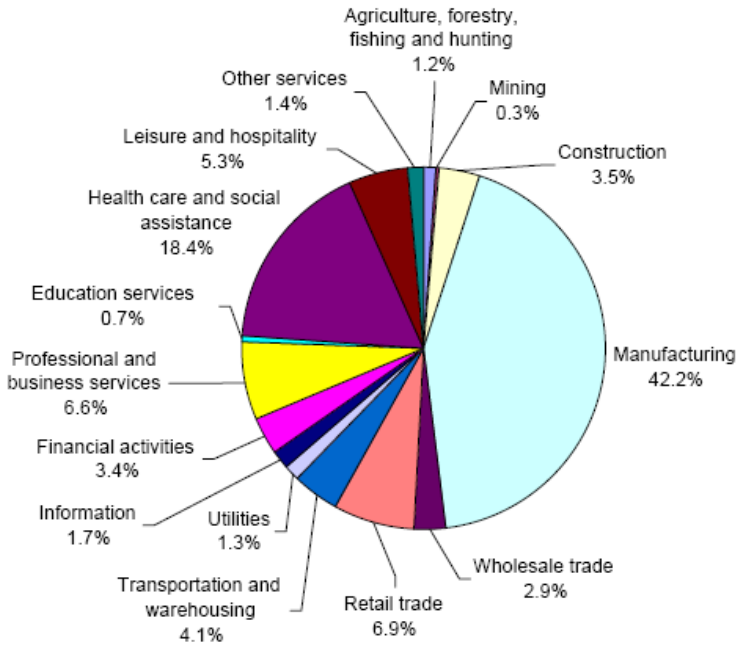


TABLE 1. **Incidence rates[1] of nonfatal occupational injuries and illnesses by selected industries and case types, 2004**

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[5]	Cases with job transfer or restriction	
Private industry[6]		107,551.8	4.8	2.5	1.4	1.1	2.3
Goods producing[6]		22,655.5	6.5	3.5	1.9	1.7	2.9
Natural resources and mining[6,7]		1,481.7	5.3	3.1	2.0	1.1	2.2
Agriculture, forestry, fishing and hunting[6]	11	961.8	6.4	3.7	2.3	1.4	2.7
Crop production[6]	111	429.8	5.6	3.3	1.7	1.5	2.3
Animal production[6]	112	141.1	8.5	4.7	2.9	1.9	3.8
Support activities for agriculture and forestry	115	309.2	5.9	3.3	2.2	1.2	2.6
Mining[7]	21	519.9	3.8	2.3	1.6	.6	1.5
Oil and gas extraction	211	121.3	2.6	1.2	.9	.3	1.4
Mining (except oil and gas)[8]	212	204.2	4.3	2.9	2.2	.7	1.4
Support activities for mining	213	194.4	3.8	2.2	1.5	.7	1.7
Construction		6,916.4	6.4	3.4	2.4	.9	3.0
Construction	23	6,916.4	6.4	3.4	2.4	.9	3.0
Construction of buildings	236	1,618.5	5.6	2.9	2.2	.7	2.7
Heavy and civil engineering construction	237	895.0	5.9	3.2	2.1	1.0	2.8
Specialty trade contractors	238	4,402.9	6.8	3.6	2.6	1.0	3.2
Manufacturing		14,257.4	6.6	3.6	1.6	2.1	3.0
Manufacturing	31-33	14,257.4	6.6	3.6	1.6	2.1	3.0
Food manufacturing	311	1,490.4	8.2	5.3	1.9	3.4	3.0
Beverage and tobacco product manufacturing	312	193.7	8.7	5.8	2.9	2.9	2.8
Textile mills	313	237.8	4.0	2.3	.8	1.5	1.7
Textile product mills	314	176.2	5.4	2.9	1.0	1.9	2.5
Apparel manufacturing	315	284.7	3.5	1.8	1.0	.8	1.7
Leather and allied product manufacturing	316	42.5	6.9	4.4	1.5	2.9	2.4
Wood product manufacturing	321	548.0	10.0	5.4	2.7	2.7	4.6
Paper manufacturing	322	493.3	4.9	2.9	1.4	1.5	2.1
Printing and related support activities	323	658.5	4.5	2.4	1.2	1.2	2.0
Petroleum and coal products manufacturing	324	112.3	2.5	1.2	.7	.5	1.2
Chemical manufacturing	325	881.8	3.5	2.0	.9	1.0	1.5
Plastics and rubber products manufacturing	326	803.7	7.7	4.7	2.0	2.7	3.0
Nonmetallic mineral product manufacturing	327	498.5	8.0	4.8	2.3	2.5	3.1

See footnotes at end of table.

TABLE 1. **Incidence rates[1] of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[5]	Cases with job transfer or restriction	
Primary metal manufacturing	331	466.0	10.0	5.2	2.2	3.0	4.8
Fabricated metal product manufacturing	332	1,488.7	8.0	3.9	1.9	2.0	4.1
Machinery manufacturing	333	1,136.8	6.7	3.1	1.5	1.6	3.6
Computer and electronic product manufacturing	334	1,314.9	2.3	1.2	.6	.6	1.1
Electrical equipment, appliance, and component manufacturing	335	443.8	5.5	2.9	1.2	1.7	2.6
Transportation equipment manufacturing	336	1,763.4	8.5	4.6	1.6	3.0	3.9
Furniture and related product manufacturing	337	568.5	8.3	4.7	2.3	2.5	3.6
Miscellaneous manufacturing	339	653.6	4.5	2.5	1.2	1.3	2.0
Service providing		84,896.3	4.2	2.2	1.3	.9	2.1
Trade, transportation, and utilities[9]		25,273.3	5.5	3.1	1.8	1.3	2.3
Wholesale trade	42	5,642.5	4.5	2.7	1.5	1.2	1.8
Merchant wholesalers, durable goods	423	2,942.2	4.1	2.2	1.3	.9	1.9
Merchant wholesalers, nondurable goods	424	2,000.0	5.6	3.9	2.0	1.9	1.7
Wholesale electronic markets and agents and brokers	425	700.4	2.8	1.6	1.0	.6	1.3
Retail trade	44-45	15,060.7	5.3	2.7	1.5	1.2	2.6
Motor vehicle and parts dealers	441	1,901.3	5.1	2.2	1.4	.7	3.0
Furniture and home furnishings stores	442	563.8	5.7	3.2	1.9	1.3	2.5
Electronics and appliance stores	443	521.8	3.1	1.5	.9	–	1.6
Building material and garden equipment and supplies dealers	444	1,234.1	8.1	4.3	2.3	2.0	3.8
Food and beverage stores	445	2,818.3	6.4	3.3	1.9	1.4	3.0
Health and personal care stores	446	940.7	2.3	1.1	.7	.4	1.2
Gasoline stations	447	872.9	3.4	1.5	1.0	.5	1.9
Clothing and clothing accessories stores	448	1,367.6	2.6	.9	.6	.3	1.6
Sporting goods, hobby, book, and music stores	451	646.1	3.9	1.3	.8	.5	2.6
General merchandise stores	452	2,851.3	7.0	4.3	1.9	2.4	2.7
Miscellaneous store retailers	453	918.5	3.2	1.6	.9	.6	1.6
Nonstore retailers	454	424.4	4.8	2.8	1.6	1.2	2.0
Transportation and warehousing[9]	48-49	4,006.2	7.3	4.9	3.1	1.8	2.4
Air transportation	481	513.2	10.1	7.7	5.3	2.5	2.4
Rail transportation[9]	482	–	2.7	2.0	1.8	.2	.7
Water transportation	483	55.0	4.4	2.6	1.8	.8	1.8
Truck transportation	484	1,350.8	6.1	3.9	2.9	1.0	2.3
Transit and ground passenger transportation	485	378.4	6.1	3.6	2.8	.8	2.5
Pipeline transportation	486	37.6	2.5	1.4	1.0	.4	1.1

See footnotes at end of table.

TABLE 1. **Incidence rates[1] of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[5]	Cases with job transfer or restriction	
Scenic and sightseeing transportation	487	27.0	4.7	2.8	2.4	0.5	1.9
Support activities for transportation	488	530.6	5.3	3.5	2.2	1.3	1.9
Couriers and messengers	492	557.5	12.4	8.8	4.1	4.7	3.7
Warehousing and storage	493	555.8	9.3	5.8	2.8	3.0	3.4
Utilities	22	563.9	5.2	2.5	1.4	1.1	2.7
Utilities	221	563.9	5.2	2.5	1.4	1.1	2.7
Information		3,099.6	2.0	1.1	.8	.4	.9
Information	51	3,099.6	2.0	1.1	.8	.4	.9
Publishing industries (except Internet)	511	907.5	2.1	1.1	.7	.4	1.0
Motion picture and sound recording industries	512	380.3	–	–	.7	.2	–
Broadcasting (except Internet)	515	323.6	2.3	1.2	.7	.5	1.1
Internet publishing and broadcasting	516	29.3	2.4	.7	.5	–	1.7
Telecommunications	517	1,027.0	2.2	1.4	1.0	.4	.8
Internet service providers, web search portals, and data processing services	518	382.5	.8	.3	.2	.1	.5
Other information services	519	49.4	1.6	1.0	1.0	–	.6
Financial activities		7,890.8	1.6	.7	.5	.2	.9
Finance and insurance	52	5,813.3	.9	.3	.2	.1	.6
Monetary authorities - central bank	521	21.6	1.9	1.2	.6	.6	.7
Credit intermediation and related activities	522	2,813.1	1.0	.4	.3	.1	.6
Securities, commodity contracts, and other financial investments and related activities	523	765.2	.3	.1	.1	([10])	.2
Insurance carriers and related activities	524	2,127.9	1.1	.4	.3	.1	.7
Funds, trusts, and other financial vehicles	525	85.5	.6	.3	.2	–	.3
Real estate and rental and leasing	53	2,077.5	3.7	1.9	1.3	.7	1.8
Real estate	531	1,410.4	3.3	1.7	1.2	.5	1.6
Rental and leasing services	532	641.0	4.7	2.5	1.5	1.0	2.2
Professional and business services		16,294.8	2.4	1.3	.8	.5	1.1
Professional, scientific, and technical services	54	6,768.9	1.3	.5	.3	.2	.8
Professional, scientific, and technical services	541	6,768.9	1.3	.5	.3	.2	.8
Management of companies and enterprises	55	1,696.5	2.7	1.5	.7	–	1.2

See footnotes at end of table.

TABLE 1. **Incidence rates[1] of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[5]	Cases with job transfer or restriction	
Administrative and support and waste management and remediation services	56	7,829.4	3.7	2.2	1.4	0.8	1.5
Administrative and support services	561	7,503.5	3.4	2.0	1.3	.7	1.4
Waste management and remediation services	562	325.8	7.6	5.3	2.9	2.4	2.4
Education and health services		16,085.0	5.8	2.7	1.5	1.2	3.1
Educational services	61	2,079.2	2.5	1.0	.7	.3	1.5
Educational services	611	2,079.2	2.5	1.0	.7	.3	1.5
Health care and social assistance	62	14,005.7	6.2	2.9	1.6	1.3	3.3
Ambulatory health care services	621	4,937.5	3.3	1.2	.8	.4	2.0
Hospitals	622	4,246.7	8.3	3.4	1.9	1.5	4.9
Nursing and residential care facilities	623	2,810.2	9.7	5.8	2.9	2.8	3.9
Social assistance	624	2,011.3	3.9	2.1	1.2	.8	1.8
Leisure and hospitality		12,467.6	4.7	1.9	1.1	.8	2.8
Arts, entertainment, and recreation	71	1,852.9	5.9	3.1	1.5	1.5	2.9
Performing arts, spectator sports, and related industries	711	380.5	5.8	2.5	1.8	.7	3.3
Museums, historical sites, and similar institutions	712	116.9	5.2	2.5	1.6	1.0	2.6
Amusement, gambling, and recreation industries	713	1,355.4	6.0	3.3	1.5	1.8	2.8
Accommodation and food services	72	10,614.7	4.5	1.7	1.1	.6	2.8
Accommodation	721	1,785.0	5.8	3.1	1.6	1.5	2.7
Food services and drinking places	722	8,829.6	4.2	1.4	1.0	.4	2.8
Other services		3,785.2	3.2	1.6	1.1	.5	1.6
Other services, except public administration	81	3,785.2	3.2	1.6	1.1	.5	1.6
Repair and maintenance	811	1,222.0	3.9	1.9	1.4	.5	2.0

See footnotes at end of table.

TABLE 1. **Incidence rates[1] of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[5]	Cases with job transfer or restriction	
Personal and laundry services	812	1,266.1	2.8	1.6	1.0	0.7	1.2
Religious, grantmaking, civic, professional, and similar organizations	813	1,297.2	2.7	1.2	.8	.4	1.6

[1] The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

N = number of injuries and illnesses
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Totals include data for industries not shown separately.
[3] *North American Industry Classification System* — United States, 2002
[4] Employment is expressed as an annual average and is derived primarily from the BLS-Quarterly Census of Employment and Wages (QCEW) program.
[5] Days-away-from-work cases include those that result in days away from work with or without job transfer or restriction.
[6] Excludes farms with fewer than 11 employees.
[7] Data for Mining (Sector 21 in the *North American Industry Classification System*-- United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[8] Data for mining operators in this industry are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[9] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.
[10] Incidence rate less than 0.05.

NOTE: Because of rounding, components may not add to totals. Dash indicates data not available.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 2. **Numbers of nonfatal occupational injuries and illnesses by selected industries and case types, 2004**

(thousands)

Industry[1]	NAICS code[2]	2004 Annual average employment[3]	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[4]	Cases with job transfer or restriction	
Private industry[5]		107,551.8	4,257.3	2,225.0	1,259.3	965.7	2,032.3
Goods producing[5]		22,655.5	1,419.3	776.5	408.4	368.1	642.8
Natural resources and mining[5,6]		1,481.7	76.3	44.5	29.1	15.4	31.9
Agriculture, forestry, fishing and hunting[5]	11	961.8	54.7	31.5	19.8	11.8	23.2
Crop production[5]	111	429.8	21.1	12.3	6.6	5.8	8.8
Animal production[5]	112	141.1	12.6	7.0	4.2	2.8	5.6
Support activities for agriculture and forestry	115	309.2	15.3	8.6	5.6	3.0	6.7
Mining[6]	21	519.9	21.6	12.9	9.4	3.6	8.7
Oil and gas extraction	211	121.3	3.2	1.5	1.1	.4	1.7
Mining (except oil and gas)[7]	212	204.2	10.1	6.8	5.1	1.7	3.2
Support activities for mining	213	194.4	8.3	4.7	3.2	1.5	3.7
Construction		6,916.4	401.0	212.2	153.2	59.0	188.9
Construction	23	6,916.4	401.0	212.2	153.2	59.0	188.9
Construction of buildings	236	1,618.5	81.1	42.5	32.0	10.5	38.6
Heavy and civil engineering construction	237	895.0	50.8	27.2	18.3	8.9	23.6
Specialty trade contractors	238	4,402.9	269.1	142.5	102.9	39.6	126.6
Manufacturing		14,257.4	941.9	519.9	226.1	293.8	422.1
Manufacturing	31-33	14,257.4	941.9	519.9	226.1	293.8	422.1
Food manufacturing	311	1,490.4	122.3	78.3	27.6	50.7	44.0
Beverage and tobacco product manufacturing	312	193.7	16.6	11.2	5.6	5.6	5.4
Textile mills	313	237.8	9.4	5.4	1.9	3.5	4.1
Textile product mills	314	176.2	9.5	5.0	1.8	3.2	4.4
Apparel manufacturing	315	284.7	8.8	4.4	2.5	1.9	4.3
Leather and allied product manufacturing	316	42.5	2.8	1.8	.6	1.2	1.0
Wood product manufacturing	321	548.0	54.8	29.7	15.0	14.7	25.1
Paper manufacturing	322	493.3	25.3	14.6	7.1	7.6	10.7
Printing and related support activities	323	658.5	28.2	15.2	7.7	7.5	13.0
Petroleum and coal products manufacturing	324	112.3	3.1	1.6	.9	.7	1.5
Chemical manufacturing	325	881.8	31.1	17.4	8.1	9.3	13.7

See footnotes at end of table.

TABLE 2. **Numbers of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

(thousands)

Industry[1]	NAICS code[2]	2004 Annual average employment[3]	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[4]	Cases with job transfer or restriction	
Plastics and rubber products manufacturing	326	803.7	62.6	38.2	16.6	21.6	24.4
Nonmetallic mineral product manufacturing	327	498.5	40.4	24.5	11.6	12.9	15.9
Primary metal manufacturing	331	466.0	49.0	25.4	10.7	14.7	23.6
Fabricated metal product manufacturing	332	1,488.7	119.9	58.1	28.6	29.5	61.8
Machinery manufacturing	333	1,136.8	77.7	36.0	17.8	18.2	41.7
Computer and electronic product manufacturing	334	1,314.9	30.5	16.0	8.0	8.0	14.6
Electrical equipment, appliance, and component manufacturing	335	443.8	24.1	12.8	5.3	7.5	11.3
Transportation equipment manufacturing	336	1,763.4	151.5	82.6	28.4	54.1	68.9
Furniture and related product manufacturing	337	568.5	46.0	26.0	12.4	13.6	20.0
Miscellaneous manufacturing	339	653.6	28.4	15.7	7.8	7.9	12.7
Service providing		84,896.3	2,838.0	1,448.5	850.9	597.6	1,389.5
Trade, transportation, and utilities[8]		25,273.3	1,182.2	673.1	387.6	285.4	509.1
Wholesale trade	42	5,642.5	241.5	146.2	81.1	65.0	95.3
Merchant wholesalers, durable goods	423	2,942.2	117.5	63.1	37.3	25.8	54.4
Merchant wholesalers, nondurable goods	424	2,000.0	105.7	72.9	37.6	35.4	32.8
Wholesale electronic markets and agents and brokers	425	700.4	18.2	10.1	6.2	3.8	8.1
Retail trade	44-45	15,060.7	626.1	322.8	178.8	144.0	303.3
Motor vehicle and parts dealers	441	1,901.3	92.3	39.1	25.9	13.1	53.2
Furniture and home furnishings stores	442	563.8	26.6	14.9	9.0	6.0	11.7
Electronics and appliance stores	443	521.8	13.4	6.4	3.7	–	7.0
Building material and garden equipment and supplies dealers	444	1,234.1	92.9	49.1	25.8	23.3	43.8
Food and beverage stores	445	2,818.3	135.0	70.7	41.2	29.5	64.2
Health and personal care stores	446	940.7	15.4	7.3	4.6	2.8	8.1
Gasoline stations	447	872.9	23.8	10.5	7.1	3.4	13.3
Clothing and clothing accessories stores	448	1,367.6	23.7	8.7	5.8	2.9	15.0
Sporting goods, hobby, book, and music stores	451	646.1	17.2	5.9	3.6	2.3	11.3
General merchandise stores	452	2,851.3	146.1	89.1	39.9	49.2	57.1
Miscellaneous store retailers	453	918.5	21.6	10.6	6.3	4.3	11.0
Nonstore retailers	454	424.4	18.1	10.5	6.0	4.5	7.6
Transportation and warehousing[8]	48-49	4,006.2	285.5	190.0	120.0	70.0	95.5
Air transportation	481	513.2	43.3	33.0	22.4	10.6	10.3
Rail transportation[8]	482	–	6.2	4.6	4.1	.6	1.6

See footnotes at end of table.

TABLE 2. **Numbers of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

(thousands)

Industry[1]	NAICS code[2]	2004 Annual average employment[3]	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[4]	Cases with job transfer or restriction	
Water transportation	483	55.0	2.5	1.5	1.0	0.4	1.0
Truck transportation	484	1,350.8	86.6	54.8	40.9	13.9	31.8
Transit and ground passenger transportation	485	378.4	17.3	10.2	7.9	2.3	7.1
Pipeline transportation	486	37.6	.9	.5	.4	.2	.4
Scenic and sightseeing transportation	487	27.0	1.0	.6	.5	.1	.4
Support activities for transportation	488	530.6	27.2	17.6	11.0	6.6	9.6
Couriers and messengers	492	557.5	52.6	37.1	17.3	19.8	15.5
Warehousing and storage	493	555.8	48.0	30.2	14.6	15.6	17.8
Utilities	22	563.9	29.1	14.1	7.7	6.4	15.0
Utilities	221	563.9	29.1	14.1	7.7	6.4	15.0
Information		3,099.6	57.6	31.1	21.1	10.0	26.5
Information	51	3,099.6	57.6	31.1	21.1	10.0	26.5
Publishing industries (except Internet)	511	907.5	17.6	9.1	5.7	3.5	8.4
Motion picture and sound recording industries	512	380.3	–	–	2.2	.6	–
Broadcasting (except Internet)	515	323.6	6.5	3.3	1.9	1.4	3.2
Internet publishing and broadcasting	516	29.3	.7	.2	.2	–	.5
Telecommunications	517	1,027.0	21.8	14.2	10.1	4.1	7.6
Internet service providers, web search portals, and data processing services	518	382.5	2.9	1.1	.8	.4	1.8
Other information services	519	49.4	.6	.4	.4	–	.2
Financial activities		7,890.8	113.3	51.8	34.9	16.9	61.5
Finance and insurance	52	5,813.3	49.1	18.4	12.9	5.5	30.7
Monetary authorities - central bank	521	21.6	.4	.2	.1	.1	.1
Credit intermediation and related activities	522	2,813.1	25.0	9.6	6.8	2.8	15.4
Securities, commodity contracts, and other financial investments and related activities	523	765.2	2.2	.9	.7	.3	1.2
Insurance carriers and related activities	524	2,127.9	21.1	7.4	5.2	2.2	13.7
Funds, trusts, and other financial vehicles	525	85.5	.5	.2	.2	–	.2
Real estate and rental and leasing	53	2,077.5	64.2	33.4	22.0	11.4	30.8
Real estate	531	1,410.4	38.4	19.8	13.6	6.1	18.7
Rental and leasing services	532	641.0	25.4	13.5	8.2	5.2	11.9

See footnotes at end of table.

TABLE 2. **Numbers of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

(thousands)

Industry[1]	NAICS code[2]	2004 Annual average employment[3]	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[4]	Cases with job transfer or restriction	
Professional and business services		16,294.8	280.3	150.5	90.5	60.0	129.8
Professional, scientific, and technical services	54	6,768.9	79.1	32.2	20.4	11.8	46.9
Professional, scientific, and technical services	541	6,768.9	79.1	32.2	20.4	11.8	46.9
Management of companies and enterprises	55	1,696.5	41.9	23.4	10.3	–	18.6
Administrative and support and waste management and remediation services	56	7,829.4	159.3	94.9	59.9	35.1	64.4
Administrative and support services	561	7,503.5	134.4	77.7	50.4	27.3	56.7
Waste management and remediation services	562	325.8	24.9	17.2	9.4	7.8	7.7
Education and health services		16,085.0	720.5	337.3	190.0	147.3	383.2
Educational services	61	2,079.2	36.5	14.5	10.1	4.4	22.0
Educational services	611	2,079.2	36.5	14.5	10.1	4.4	22.0
Health care and social assistance	62	14,005.7	684.0	322.8	179.9	142.9	361.2
Ambulatory health care services	621	4,937.5	124.6	46.4	31.3	15.2	78.1
Hospitals	622	4,246.7	284.6	116.1	63.9	52.2	168.5
Nursing and residential care facilities	623	2,810.2	215.2	128.5	65.6	62.9	86.7
Social assistance	624	2,011.3	59.6	31.7	19.1	12.6	27.9
Leisure and hospitality		12,467.6	389.5	157.7	95.4	62.3	231.8
Arts, entertainment, and recreation	71	1,852.9	68.2	35.2	17.8	17.5	33.0
Performing arts, spectator sports, and related industries	711	380.5	13.9	6.0	4.3	1.7	7.9
Museums, historical sites, and similar institutions	712	116.9	4.0	2.0	1.2	.7	2.0
Amusement, gambling, and recreation industries	713	1,355.4	50.3	27.2	12.2	15.0	23.1
Accommodation and food services	72	10,614.7	321.3	122.5	77.6	44.9	198.8
Accommodation	721	1,785.0	77.5	41.1	21.0	20.1	36.4
Food services and drinking places	722	8,829.6	243.8	81.4	56.7	24.8	162.4
Other services		3,785.2	94.6	47.0	31.3	15.7	47.6
Other services, except public administration	81	3,785.2	94.6	47.0	31.3	15.7	47.6

See footnotes at end of table.

TABLE 2. **Numbers of nonfatal occupational injuries and illnesses by selected industries and case types, 2004** — Continued

(thousands)

Industry[1]	NAICS code[2]	2004 Annual average employment[3]	Total recordable cases	Cases with days away from work, job transfer, or restriction			Other recordable cases
				Total	Cases with days away from work[4]	Cases with job transfer or restriction	
Repair and maintenance	811	1,222.0	43.7	21.2	15.1	6.1	22.5
Personal and laundry services	812	1,266.1	27.0	15.5	9.1	6.4	11.5
Religious, grantmaking, civic, professional, and similar organizations	813	1,297.2	23.9	10.3	7.1	3.2	13.6

[1] Totals include data for industries not shown separately.
[2] *North American Industry Classification System* — United States, 2002
[3] Employment is expressed as an annual average and is derived primarily from the BLS-Quarterly Census of Employment and Wages (QCEW) program.
[4] Days-away-from-work cases include those that result in days away from work with or without job transfer or restriction.
[5] Excludes farms with fewer than 11 employees.
[6] Data for Mining (Sector 21 in the *North American Industry Classification System*-- United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[7] Data for mining operators in this industry are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[8] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.

NOTE: Because of rounding, components may not add to totals. Dash indicates data not available.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 3. **Incidence rates[1] of nonfatal occupational injuries and illnesses by major industry sector and employment size, 2004**

Industry sector	All establishments	Establishment employment size (workers)				
		1 to 10	11 to 49	50 to 249	250 to 999	1,000 or more
Private industry[2]	4.8	1.9	4.2	5.9	5.4	5.4
Goods producing[2]	6.5	3.6	6.8	7.6	6.1	5.8
Natural resources and mining[2,3]	5.3	3.3	5.7	5.8	5.3	3.4
Construction	6.4	3.9	7.1	7.5	5.7	6.3
Manufacturing	6.6	2.9	6.7	7.8	6.2	5.9
Service providing	4.2	1.5	3.6	5.4	5.0	5.2
Trade, transportation, and utilities[4]	5.5	2.0	4.6	6.9	7.0	6.8
Information	2.0	–	–	2.1	2.1	1.8
Financial activities	1.6	1.3	1.6	2.1	1.8	1.1
Professional and business services	2.4	–	2.9	2.8	2.3	1.7
Education and health services	5.8	1.1	3.2	7.1	7.2	7.2
Leisure and hospitality	4.7	1.4	3.8	5.8	6.4	7.0
Other services, except public administration	3.2	1.8	3.4	5.2	4.4	4.1

[1] The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

N = number of injuries and illnesses
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Excludes farms with fewer than 11 employees.

[3] Data for Mining (Sector 21 in the *North American Industry Classification System*-- United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.

[4] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.

NOTE: Dash indicates data not available.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 4. **Number of cases and incidence rate[1] of nonfatal occupational injuries and illnesses for industries with 100,000 or more cases, 2004**

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Total cases (thousands)	Incidence rate
Hospitals	622	4,246.7	284.6	8.3
Nursing and residential care facilities	623	2,810.2	215.2	9.7
Transportation equipment manufacturing	336	1,763.4	151.5	8.5
General merchandise stores	452	2,851.3	146.1	7.0
Administrative and support services	561	7,503.5	134.4	3.4
Ambulatory health care services	621	4,937.5	124.6	3.3
Food manufacturing	311	1,490.4	122.3	8.2
Fabricated metal product manufacturing	332	1,488.7	119.9	8.0
Merchant wholesalers, durable goods	423	2,942.2	117.5	4.1
Building equipment contractors	2382	1,848.2	117.2	6.8
Supermarkets and other grocery (except convenience) stores	44511	2,298.3	114.1	6.7
Full-service restaurants	7221	4,194.9	113.3	4.1
Merchant wholesalers, nondurable goods	424	2,000.0	105.7	5.6
Limited-service eating places	7222	3,737.3	104.2	4.3
Private industry[5]		107,551.8	4,257.3	4.8

[1] The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

N = number of injuries and illnesses
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Totals include data for industries not shown separately.

[3] *North American Industry Classification System* — United States, 2002

[4] Employment is expressed as an annual average and is derived primarily from the BLS-Quarterly Census of Employment and Wages (QCEW) program.

[5] Excludes farms with fewer than 11 employees.

SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 5. **Incidence rate[1] and number of nonfatal occupational injuries by selected industries, 2004**

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Incidence rate	Number of cases (thousands)
Private industry[5]		107,551.8	4.5	4,008.3
Goods producing[5]		22,655.5	5.9	1,301.7
Natural resources and mining[5,6]		1,481.7	5.1	72.6
Agriculture, forestry, fishing and hunting[5]	11	961.8	6.0	51.8
Crop production[5]	111	429.8	5.1	19.5
Animal production[5]	112	141.1	8.3	12.3
Support activities for agriculture and forestry	115	309.2	5.6	14.5
Mining[6]	21	519.9	3.6	20.9
Oil and gas extraction	211	121.3	2.4	2.9
Mining (except oil and gas)[7]	212	204.2	4.1	9.7
Support activities for mining	213	194.4	3.8	8.2
Construction		6,916.4	6.2	392.4
Construction	23	6,916.4	6.2	392.4
Construction of buildings	236	1,618.5	5.5	79.2
Heavy and civil engineering construction	237	895.0	5.8	49.4
Specialty trade contractors	238	4,402.9	6.6	263.8
Manufacturing		14,257.4	5.9	836.7
Manufacturing	31-33	14,257.4	5.9	836.7
Food manufacturing	311	1,490.4	6.8	101.2
Beverage and tobacco product manufacturing	312	193.7	8.3	15.8
Textile mills	313	237.8	3.6	8.6
Textile product mills	314	176.2	4.7	8.3
Apparel manufacturing	315	284.7	3.1	7.7
Leather and allied product manufacturing	316	42.5	5.7	2.3
Wood product manufacturing	321	548.0	9.5	51.8
Paper manufacturing	322	493.3	4.5	23.1
Printing and related support activities	323	658.5	4.1	26.0
Petroleum and coal products manufacturing	324	112.3	2.2	2.7
Chemical manufacturing	325	881.8	3.0	26.7
Plastics and rubber products manufacturing	326	803.7	7.1	57.5
Nonmetallic mineral product manufacturing	327	498.5	7.5	38.1
Primary metal manufacturing	331	466.0	9.1	44.7
Fabricated metal product manufacturing	332	1,488.7	7.5	111.7

See footnotes at end of table.

TABLE 5. **Incidence rate[1] and number of nonfatal occupational injuries by selected industries, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Incidence rate	Number of cases (thousands)
Machinery manufacturing	333	1,136.8	6.2	71.7
Computer and electronic product manufacturing	334	1,314.9	2.0	26.3
Electrical equipment, appliance, and component manufacturing	335	443.8	4.8	21.3
Transportation equipment manufacturing	336	1,763.4	6.9	123.5
Furniture and related product manufacturing	337	568.5	7.7	42.3
Miscellaneous manufacturing	339	653.6	4.0	25.3
Service providing		84,896.3	4.0	2,706.5
Trade, transportation, and utilities[5]		25,273.3	5.3	1,144.2
Wholesale trade	42	5,642.5	4.4	234.4
Merchant wholesalers, durable goods	423	2,942.2	4.0	113.4
Merchant wholesalers, nondurable goods	424	2,000.0	5.5	103.3
Wholesale electronic markets and agents and brokers	425	700.4	2.8	17.7
Retail trade	44-45	15,060.7	5.1	608.8
Motor vehicle and parts dealers	441	1,901.3	5.0	89.8
Furniture and home furnishings stores	442	563.8	5.6	26.2
Electronics and appliance stores	443	521.8	3.1	13.2
Building material and garden equipment and supplies dealers	444	1,234.1	8.0	91.4
Food and beverage stores	445	2,818.3	6.2	131.5
Health and personal care stores	446	940.7	2.2	14.9
Gasoline stations	447	872.9	3.4	23.4
Clothing and clothing accessories stores	448	1,367.6	2.5	23.4
Sporting goods, hobby, book, and music stores	451	646.1	3.8	16.8
General merchandise stores	452	2,851.3	6.7	140.2
Miscellaneous store retailers	453	918.5	3.1	20.8
Nonstore retailers	454	424.4	4.6	17.2
Transportation and warehousing[6]	48-49	4,006.2	7.0	275.2
Air transportation	481	513.2	9.7	41.3
Rail transportation[6]	482	–	2.6	6.0
Water transportation	483	55.0	4.2	2.4
Truck transportation	484	1,350.8	6.0	85.3
Transit and ground passenger transportation	485	378.4	5.9	16.8
Pipeline transportation	486	37.6	2.4	.9
Scenic and sightseeing transportation	487	27.0	4.6	1.0
Support activities for transportation	488	530.6	5.2	26.4
Couriers and messengers	492	557.5	11.7	49.3
Warehousing and storage	493	555.8	8.9	46.0

See footnotes at end of table.

TABLE 5. **Incidence rate[1] and number of nonfatal occupational injuries by selected industries, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Incidence rate	Number of cases (thousands)
Utilities	22	563.9	4.6	25.8
Utilities	221	563.9	4.6	25.8
Information		3,099.6	1.9	53.3
Information	51	3,099.6	1.9	53.3
Publishing industries (except Internet)	511	907.5	1.9	16.0
Motion picture and sound recording industries	512	380.3	–	–
Broadcasting (except Internet)	515	323.6	2.2	6.4
Internet publishing and broadcasting	516	29.3	2.2	.6
Telecommunications	517	1,027.0	2.0	19.9
Internet service providers, web search portals, and data processing services	518	382.5	.8	2.7
Other information services	519	49.4	1.3	.5
Financial activities		7,890.8	1.5	104.8
Finance and insurance	52	5,813.3	.8	42.7
Monetary authorities - central bank	521	21.6	1.5	.3
Credit intermediation and related activities	522	2,813.1	.8	21.7
Securities, commodity contracts, and other financial investments and related activities	523	765.2	.3	1.9
Insurance carriers and related activities	524	2,127.9	1.0	18.3
Funds, trusts, and other financial vehicles	525	85.5	.6	.4
Real estate and rental and leasing	53	2,077.5	3.6	62.1
Real estate	531	1,410.4	3.2	36.8
Rental and leasing services	532	641.0	4.6	25.0
Professional and business services		16,294.8	2.2	263.8
Professional, scientific, and technical services	54	6,768.9	1.2	72.7
Professional, scientific, and technical services	541	6,768.9	1.2	72.7
Management of companies and enterprises	55	1,696.5	2.5	39.4
Administrative and support and waste management and remediation services	56	7,829.4	3.6	151.8
Administrative and support services	561	7,503.5	3.2	127.4
Waste management and remediation services	562	325.8	7.5	24.4

See footnotes at end of table.

TABLE 5. **Incidence rate[1] and number of nonfatal occupational injuries by selected industries, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Incidence rate	Number of cases (thousands)
Education and health services		16,085.0	5.4	672.9
Educational services	61	2,079.2	2.4	34.9
Educational services	611	2,079.2	2.4	34.9
Health care and social assistance	62	14,005.7	5.8	638.0
Ambulatory health care services	621	4,937.5	3.0	115.3
Hospitals	622	4,246.7	7.6	259.6
Nursing and residential care facilities	623	2,810.2	9.2	205.7
Social assistance	624	2,011.3	3.7	57.5
Leisure and hospitality		12,467.6	4.5	376.4
Arts, entertainment, and recreation	71	1,852.9	5.6	64.3
Performing arts, spectator sports, and related industries	711	380.5	5.7	13.6
Museums, historical sites, and similar institutions	712	116.9	4.9	3.7
Amusement, gambling, and recreation industries	713	1,355.4	5.6	46.9
Accommodation and food services	72	10,614.7	4.4	312.1
Accommodation	721	1,785.0	5.6	74.8
Food services and drinking places	722	8,829.6	4.1	237.4
Other services		3,785.2	3.1	91.1
Other services, except public administration	81	3,785.2	3.1	91.1

See footnotes at end of table.

TABLE 5. **Incidence rate[1] and number of nonfatal occupational injuries by selected industries, 2004** — Continued

Industry[2]	NAICS code[3]	2004 Annual average employment[4] (thousands)	Incidence rate	Number of cases (thousands)
Repair and maintenance	811	1,222.0	3.9	42.7
Personal and laundry services	812	1,266.1	2.7	25.8
Religious, grantmaking, civic, professional, and similar organizations	813	1,297.2	2.6	22.5

[1] The incidence rates represent the number of injuries per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

N = number of injuries
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Totals include data for industries not shown separately.
[3] *North American Industry Classification System* — United States, 2002
[4] Employment is expressed as an annual average and is derived primarily from the BLS-Quarterly Census of Employment and Wages (QCEW) program.
[5] Excludes farms with fewer than 11 employees.
[6] Data for Mining (Sector 21 in the *North American Industry Classification System*–United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[7] Data for mining operators in this industry are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.
[8] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.

NOTE: Because of rounding, components may not add to totals. Dash indicates data not available.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 6. **Incidence rates[1] and numbers of nonfatal occupational illnesses by major industry sector and category of illness, 2004**

Industry sector	Total cases	Skin diseases or disorders	Respiratory conditions	Poisonings	Hearing loss	All other illnesses
	Incidence rates per 10,000 full-time workers					
Private industry[2]	27.9	4.4	2.0	0.4	3.2	18.0
Goods producing[2]	53.5	6.4	2.1	.6	11.1	33.4
Natural resources and mining[2,3]	25.8	7.2	1.7	2.3	1.5	13.1
Construction	13.8	3.7	1.0	.9	.4	7.9
Manufacturing	73.8	7.4	2.6	.3	16.7	46.7
Service providing	19.6	3.7	1.9	.3	.6	13.0
Trade, transportation, and utilities[4]	17.5	2.8	1.3	.2	1.5	11.6
Information	15.4	2.0	1.0	.4	1.0	10.9
Financial activities	12.0	1.3	.9	.4	([5])	9.4
Professional and business services	13.9	4.0	1.3	.3	.3	8.0
Education and health services	38.2	6.0	4.8	.4	.1	26.9
Leisure and hospitality	15.8	5.3	1.4	.2	([5])	8.9
Other services, except public administration	12.1	2.6	1.7	.4	.1	7.2
	Numbers of illnesses in thousands					
Private industry[2]	249.0	38.9	17.6	3.3	28.4	160.9
Goods producing[2]	117.6	14.0	4.6	1.3	24.3	73.4
Natural resources and mining[2,3]	3.7	1.0	.2	.3	.2	1.9
Construction	8.7	2.3	.6	.5	.3	4.9
Manufacturing	105.2	10.6	3.8	.4	23.8	66.6
Service providing	131.5	24.9	13.0	2.0	4.1	87.4
Trade, transportation, and utilities[4]	37.9	6.1	2.9	.5	3.2	25.2
Information	4.3	.6	.3	.1	.3	3.1
Financial activities	8.5	.9	.6	.3	([6])	6.6
Professional and business services	16.5	4.7	1.6	.3	.4	9.5
Education and health services	47.6	7.4	6.0	.5	.2	33.5
Leisure and hospitality	13.1	4.4	1.1	.2	([6])	7.4
Other services, except public administration	3.5	.8	.5	.1	([6])	2.1

[1] The incidence rates represent the number of illnesses per 10,000 full-time workers and were calculated as: (N/EH) x 20,000,000, where

N = number of illnesses
EH = total hours worked by all employees during the calendar year
20,000,000 = base for 10,000 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Excludes farms with fewer than 11 employees.

[3] Data for Mining (Sector 21 in the *North American Industry Classification System*-- United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.

[4] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.

[5] Incidence rate less than 0.05.

[6] Fewer than 50 cases.

NOTE: Because of rounding, components may not add to totals.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

TABLE 7. **Incidence rates[1] of nonfatal occupational injuries and illnesses by major industry sector and selected case types, 2003-2004**

Industry sector	Total recordable cases		Cases with days away from work, job transfer, or restriction						Other recordable cases	
			Total		Cases with days away from work[2]		Cases with job transfer or restriction			
	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
Private industry[3]	5.0	4.8	2.6	2.5	1.5	1.4	1.1	1.1	2.4	2.3
Goods producing[3]	6.7	6.5	3.7	3.5	1.9	1.9	1.8	1.7	3.0	2.9
Natural resources and mining[3,4]	5.1	5.3	2.8	3.1	1.8	2.0	1.0	1.1	2.3	2.2
Construction	6.8	6.4	3.6	3.4	2.6	2.4	1.0	.9	3.2	3.0
Manufacturing	6.8	6.6	3.8	3.6	1.6	1.6	2.2	2.1	3.1	3.0
Service providing	4.4	4.2	2.3	2.2	1.4	1.3	.9	.9	2.1	2.1
Trade, transportation, and utilities[5]	5.5	5.5	3.2	3.1	1.9	1.8	1.3	1.3	2.4	2.3
Information	2.2	2.0	1.1	1.1	.8	.8	.3	.4	1.1	.9
Financial activities	1.7	1.6	.8	.7	.6	.5	.2	.2	.9	.9
Professional and business services	2.5	2.4	1.4	1.3	.9	.8	.5	.5	1.1	1.1
Education and health services	6.0	5.8	2.9	2.7	1.6	1.5	1.3	1.2	3.1	3.1
Leisure and hospitality	5.1	4.7	2.1	1.9	1.3	1.1	.8	.8	3.0	2.8
Other services, except public administration	3.4	3.2	1.7	1.6	1.1	1.1	.6	.5	1.7	1.6

[1] The incidence rates represent the number of injuries and illnesses per 100 full-time workers and were calculated as: (N/EH) x 200,000, where

N = number of injuries and illnesses
EH = total hours worked by all employees during the calendar year
200,000 = base for 100 equivalent full-time workers (working 40 hours per week, 50 weeks per year)

[2] Days-away-from-work cases include those that result in days away from work with or without job transfer or restriction.

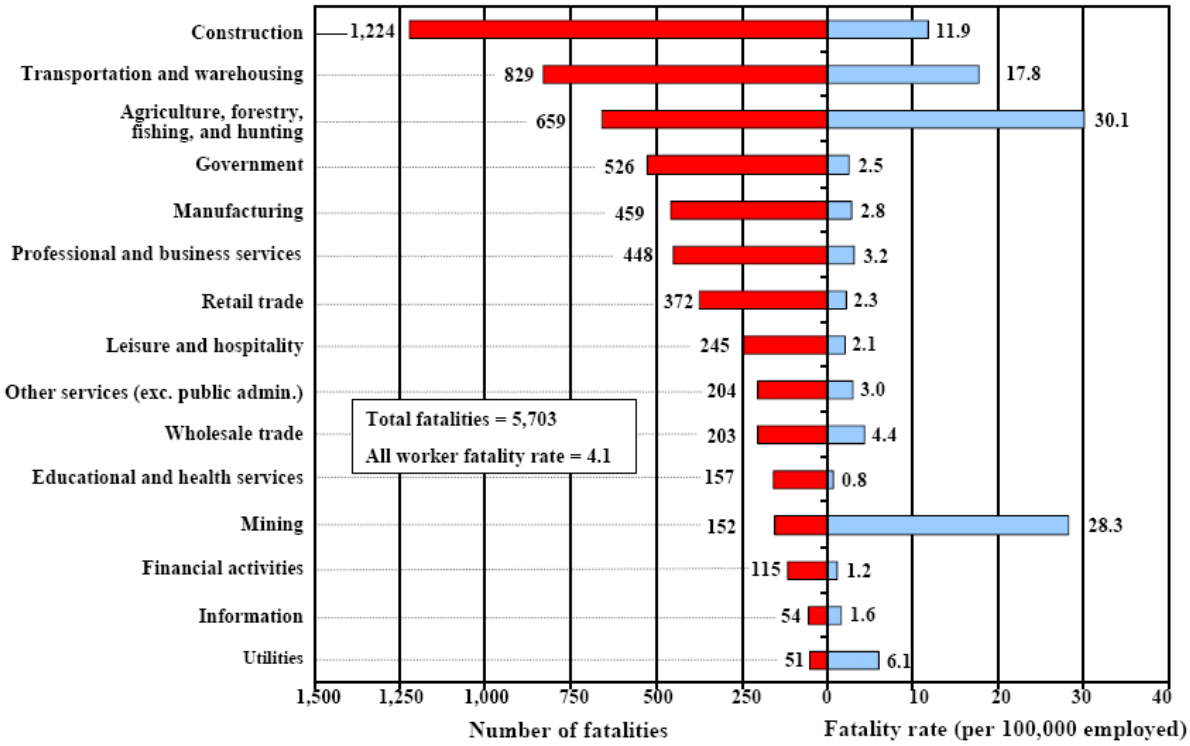
[3] Excludes farms with fewer than 11 employees.

[4] Data for Mining (Sector 21 in the *North American Industry Classification System*-- United States, 2002) include establishments not governed by the Mine Safety and Health Administration rules and reporting, such as those in Oil and Gas Extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes the Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore, estimates for these industries are not comparable to estimates in other industries.

[5] Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation.

NOTE: Because of rounding, components may not add to totals.
SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

Number and rate of fatal occupational injuries by industry sector[1], 2004



1 Individual industry sectors exclude data for employees of governmental agencies, which are provided separately.
Rate = (Fatal work injuries/Employment) x 100,000. Employment data based on the 2004 Current Population Survey (CPS) and Department of Defense (DOD) figures.
SOURCE: US Department of Labor, Bureau of Labor Statistics, Current Population Survey, Census of Fatal Occupational Injuries, and US Department of Defense, 2004.

Table 1. Fatal occupational injuries by event or exposure, 1999-2004

Event or exposure[1]	Fatalities			
	1999-2003 average	2003[2]	2004	
		Number	Number	Percent
Total	5,800	5,575	5,703	100
Transportation incidents	2,493	2,364	2,460	43
Highway	1,399	1,353	1,374	24
Collision between vehicles, mobile equipment	684	648	687	12
Moving in same direction	139	135	145	3
Moving in opposite directions, oncoming	248	269	270	5
Moving in intersection	145	124	144	3
Vehicle struck stationary object or equipment in roadway	27	17	27	([3])
Vehicle struck stationary object, equipment on side of road	289	327	314	6
Noncollision	356	321	316	6
Jack-knifed or overturned-no collision	293	252	257	5
Nonhighway (farm, industrial premises)	349	347	335	6
Overturned	185	186	181	3
Worker struck by a vehicle	365	337	377	7
Rail vehicle	59	43	50	1
Water vehicle	83	69	90	2
Aircraft	232	211	230	4
Assaults and violent acts	898	902	795	14
Homicides	642	632	551	10
Shooting	501	487	416	7
Stabbing	60	58	66	1
Self-inflicted injuries	217	218	200	4
Contact with objects and equipment	957	913	1,004	18
Struck by object	549	531	596	10
Struck by falling object	337	324	370	6
Struck by flying object	54	57	42	1
Caught in or compressed by equipment or objects	266	238	270	5
Caught in running equipment or machinery	139	123	142	2
Caught in or crushed in collapsing materials	123	126	117	2
Falls	736	696	815	14
Fall to lower level	647	604	732	13
Fall from ladder	114	114	133	2
Fall from roof	147	128	178	3
Fall from scaffold, staging	88	85	89	2
Fall on same level	69	71	61	1
Exposure to harmful substances or environments	508	486	459	8
Contact with electric current	271	246	253	4
Contact with overhead power lines	121	107	123	2
Contact with temperature extremes	43	42	27	([3])
Exposure to caustic, noxious, or allergenic substances	105	122	114	2
Inhalation of substance	53	65	52	1
Oxygen deficiency	86	73	63	1
Drowning, submersion	64	52	49	1
Fires and explosions	189	198	159	3

Table 2. Fatal occupational injuries by industry and selected event or exposure, 2004

Industry[1]	Fatalities		Selected event or exposure[2] (percent of total for industry)			
	Number	Percent	Highway[3]	Homicides	Falls	Struck by object
Total	5,703	100	24	10	14	10
Private industry	5,177	91	23	9	15	11
Goods producing	2,494	44	14	2	21	15
Natural resources and mining	811	14	16	1	5	20
Agriculture, forestry, fishing and hunting	659	12	15	1	5	21
Crop production	317	6	15	1	4	17
Animal production	141	2	15	–	11	10
Forestry and logging	106	2	17	–	3	60
Fishing, hunting and trapping	37	1	–	–	–	–
Agriculture and forestry support activities	45	1	16	–	–	11
Mining[4]	152	3	24	–	9	16
Oil and gas extraction	29	1	34	–	–	21
Mining, except oil and gas	51	1	10	–	10	14
Support activities for mining	71	1	30	–	10	15
Construction	1,224	21	12	2	36	12
Construction	1,224	21	12	2	36	12
Construction of buildings	224	4	11	2	46	13
Heavy and civil engineering construction	219	4	17	–	8	21
Specialty trade contractors	752	13	10	2	42	9
Manufacturing	459	8	17	3	10	14
Manufacturing	459	8	17	3	10	14
Food manufacturing	65	1	22	12	11	–
Wood product manufacturing	49	1	8	–	8	14
Paper manufacturing	19	([5])	–	–	–	–
Chemical manufacturing	31	1	13	–	–	–
Plastics and rubber products manufacturing	25	([5])	–	–	–	12
Nonmetallic mineral product manufacturing	54	1	35	–	9	9
Primary metal manufacturing	28	([5])	–	–	14	32
Service providing	2,683	47	32	16	9	7
Trade, transportation, and utilities	1,455	26	41	15	6	7
Wholesale trade	203	4	42	5	6	9
Merchant wholesalers, durable goods	99	2	29	6	6	16
Merchant wholesalers, nondurable goods	95	2	54	4	6	–
Retail trade	372	7	19	43	10	4
Motor vehicle and parts dealers	75	1	40	20	5	8
Building material and garden supply stores	39	1	26	–	15	–
Food and beverage stores	83	1	5	69	7	–
Health and personal care stores	17	([5])	24	47	18	–
Gasoline stations	44	1	7	84	–	–
Sporting goods, hobby, book and music stores	15	([5])	–	53	–	–
General merchandise stores	26	([5])	–	19	46	–
Miscellaneous store retailers	28	([5])	25	43	–	–
Nonstore retailers	15	([5])	47	–	–	–
Transportation and warehousing	829	15	52	6	4	7
Air transportation	47	1	–	–	–	–
Rail transportation	19	([5])	–	–	–	–
Water transportation	43	1	–	–	–	–
Truck transportation	508	9	72	1	3	9
Transit and ground passenger transportation	75	1	37	49	–	–
Support activities for transportation	80	1	10	6	6	18
Couriers and messengers	25	([5])	76	–	–	–
Warehousing and storage	21	([5])	–	–	38	–
Utilities	51	1	16	–	18	8
Information	54	1	48	9	6	–
Information	54	1	48	9	6	–
Publishing industries, except Internet	33	1	64	9	–	–
Financial activities	115	2	25	31	13	3
Finance and insurance	46	1	33	39	9	–
Credit intermediation and related activities	26	([5])	27	50	–	–
Real estate and rental and leasing	69	1	20	26	16	6
Real estate	45	1	11	33	22	–
Rental and leasing services	24	([5])	38	12	–	–