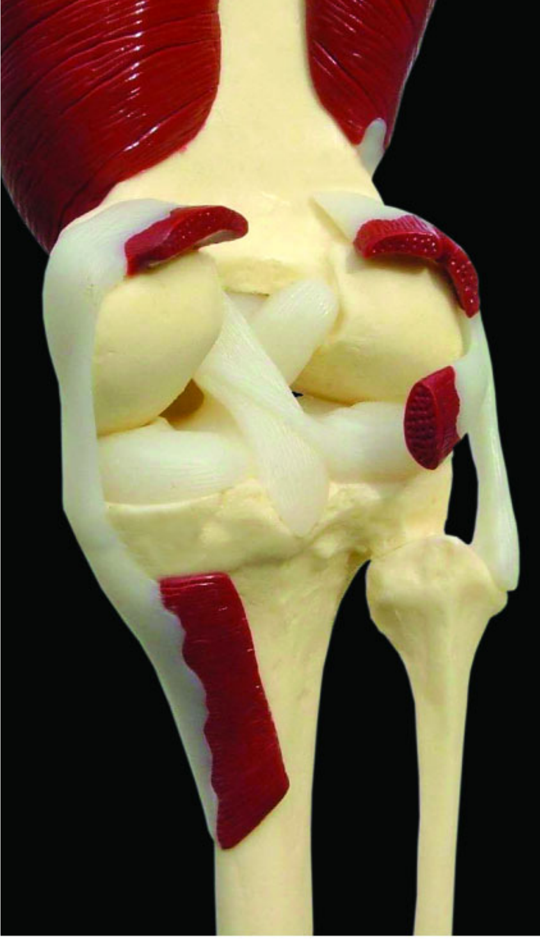

TYPES OF KNEE INJURIES & how they occur

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Key Words: knee injury, knee meniscal tears, knee ligament rupture, knee osteoarthritis, chondromalacia, knee bursitis

Abstract

The purpose of this article is to distinguish the mechanism of knee injury (e.g., forward fall while foot is trapped, impact of knee on dashboard, chronic injury due to repetitive twisting, etc.) from the type of injury (e.g., torn meniscus, ruptured ACL, bursitis, etc). While there are no absolute rules for positively associating each mechanism of injury with a specific type of injury, this article will provide some guidance for those attempting to prove or disprove the relationship between mechanism and injury type.

Scope of Paper

Before we are able to discuss types of injuries to the knee joint, we must first examine the anatomy of the knee joint and the kinematics that the structures of the knee generate. We will then discuss the relationship of mechanism of injury and the type of injury from both an anatomical point of view and by example.

Anatomy of the Knee

The knee is the largest joint in the body.[9] The femur, tibia, and patella combine to create a complex joint (Figures 1 & 2). This complex joint is comprised of three articulations: two tibiofemoral articulations (joints between bones or cartilages that are immovable when the bones are directly united) and one patellofemoral articulation.[10] The two tibiofemoral joints are created by the condyles (articular prominences of bones) of the femur and plateaus of the tibia. The medial and lateral condyles of the femur roll

Figure 1: Bony anatomy of the knee (anterior view)

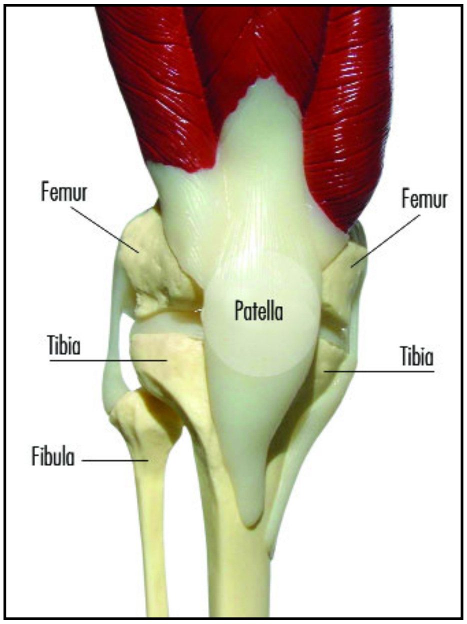


Figure 2: Bony anatomy of the knee (posterior view)

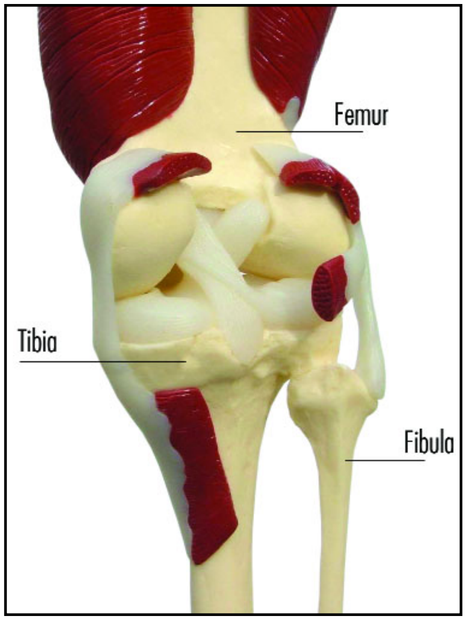
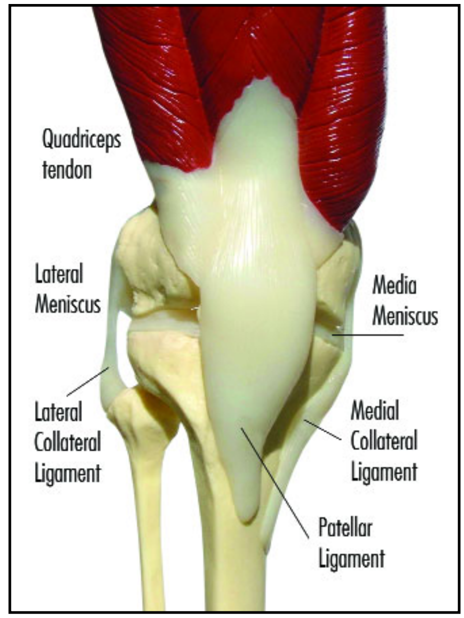


Figure 3: Ligaments & cartilage of the knee (anterior view)



and glide across the medial and lateral meniscus (fibrous cartilage within a joint) respectively. In the healthy knee, the roll and glide of the femur produce approximately 140 degrees of flexion and extension. Although flexion and extension are the dominant motions at the tibiofemoral articulations, internal rotation and external rotation are also produced at these articulations. The amount of internal and external rotation is a function of flexion and extension. Rotation is absent when the knee is in full extension, but there can be up to 30 degrees of internal rotation and 45 degrees of external rotation when the knee is in 90 degrees of flexion.[15]

The patellofemoral articulation is created by the patella and the femur. The posterior surface of the patella articulates with the trochlear groove of the femur. The trochlear groove is a U-shaped concavity located between the two condyles of the femur.[9] The patella is a sesamoid bone, which is bone that has developed within a tendon. In this case, the tendon that envelopes the patella is the quadriceps tendon. The patella's primary function is to act as a modified pulley mechanism that changes the direction of the force vector of the quadriceps. This change in the line of pull increases the momentum, and consequently the amount of torque, giving the quadriceps a mechanical advantage. Another function of the patella is to protect the anterior knee.[15]

The knee joints contain two C-shaped fibrocartilage structures, medial and lateral menisci, that are attached to the medial and lateral tibial plateaus respectively (Figures 3 & 4). The two menisci help stabilize the joint by deepening the articular surface of the tibia. They also aid in the absorption of shock and the transmission of force by increasing the articular surface area, produce synovial fluid (a source of nutrients and lubrication to the joint), and help prevent the condyles of the femur from articulating directly on the tibial plateaus, which protects against friction wear of the femur and tibia.[15]

The condyles of the femur and the tibial plateaus are covered with a hyaline cartilage called articular cartilage (Figures 1 & 2). The primary function of articular cartilage is to absorb shock in the joint.[19] The articular cartilage does this by absorbing and discharging synovial fluid as pressure changes within the joint.[2]

The anterior and posterior cruciate ligaments are thick fibrous connective tissue structures that help guide the knee during motion (Figure 4). The anterior cruciate ligament attaches to the tibia at the anterior intercondylar portion of the tibial plateau; it travels upward and backward and attaches to the femur at the intercondylar fossa (an anatomical pit, groove, or depression). The anterior cruciate ligament prevents excessive anterior translation of the tibia with respect to the femur. The posterior cruciate ligament attaches to the tibia at the posterior proximal tibial shaft and attaches to the femur at the posterior intercondylar fossa. The posterior cruciate ligament prevents excessive posterior translation of the tibia with respect to the femur.[2]

The medial and lateral collateral ligaments also help guide the knee during motion (Figures 3 & 4). The medial collateral ligament attaches to the tibia at the medial proximal tibial shaft and attaches to the femur at the medial epicondyle (any of several prominences on the outer part of a long bone). The medial collateral ligament helps protect against excessive valgus forces on the knee. The lateral collateral ligament attaches to the proximal head of the fibula and attaches to the femur on the lateral epicondyle. The lateral collateral ligament provides protection from excessive varus forces on the knee.[2]

The articular capsule of the knee is irregular in that it does not completely envelope the joint like most other synovial joints. It is covered with a synovial

Figure 4: Ligaments & cartilage of the knee (posterior view)

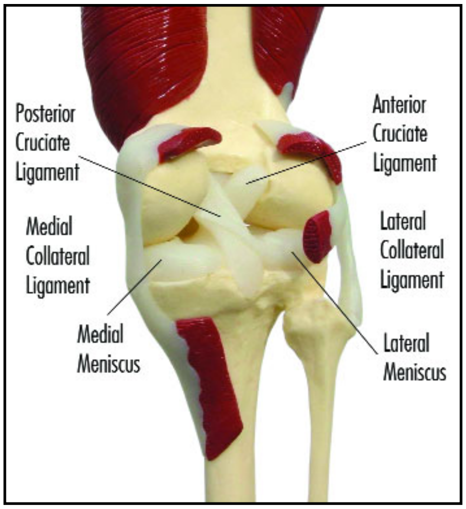


Figure 5: Anterior knee musculature

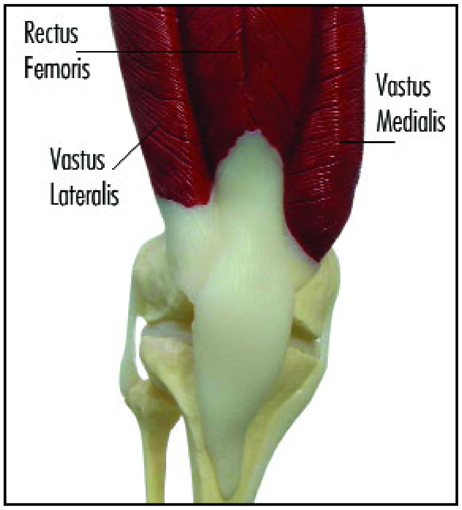
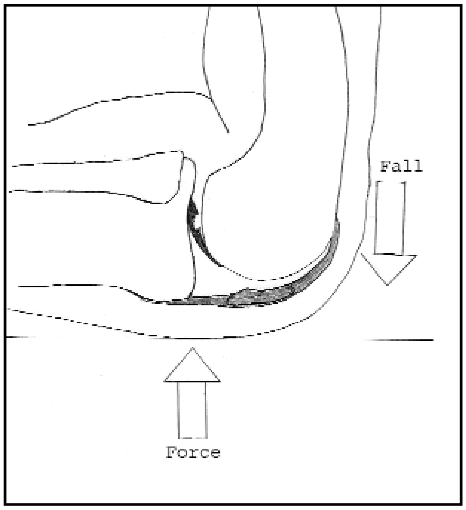


Figure 6: Tearing of the PCL as a result of falling on a flexed knee*



membrane that produces synovial fluid to lubricate and provide nutrients for the joint structures.[15]

The knee joint is crossed by 12 muscles that stabilize the joint and produce the anatomical motions of the joint. These 12 muscles can be divided into three groups: the quadriceps femoris, the hamstring, and the unclassified group. The quadriceps femoris group is comprised of the rectus femoris, vastus intermedius, vastus lateralis, and the vastus medialis (Figure 5). This muscle group is responsible for knee extension.[15] The vastus medialis, however, has an important function in providing a medial force on the patella that counterbalances the lateral components of force generated by the remaining three quadriceps muscles. The dynamic medio-lateral equilibrium created by the vastus medialis helps to maintain patellar tracking.[15] The rectus femoris also assists in hip flexion because the proximal attachment is on the anterior inferior iliac spine.[16]

The hamstring group is made up of the biceps femoris, semimembranosus, and the semitendinosus. These muscles work together to produce knee flexion and hip extension. The muscles of the hamstring group produce hip extension because they also cross the hip joint and have a proximal attachment on the ischial tuberosity of the pelvis. Only the short head of the biceps femoris does not produce hip extension due to its proximal attachment on the posterior femur.[16]

The unclassified muscle group contains the sartorius, gracilis, popliteus, gastrocnemius, and plantar muscles.[15] These muscles have less influence on the knee than the other two muscle groups. They primarily act on another joint, such as the ankle or the hip, and only assist with flexion, extension, and internal and external rotation of the tibia. The popliteus is the one exception to that statement; its primary function is to initiate internal rotation of the knee and unlock the knee at the onset of knee flexion.[6]

There are 13 bursae in the knee joint. A bursa is a sac containing a viscid fluid that helps reduce friction between moving parts. Bursae are usually found over bony prominences and beneath tendons.[5] The knee bursae are grouped in three general areas: the anterior bursae, medial bursae, and lateral bursae. The anterior bursae consist of the deep infrapatellar bursa, subcutaneous prepatellar bursa, subcutaneous infrapatellar bursa, and suprapatellar bursa. The medial bursae consist of the bursa between the medial head of the gastrocnemius and the fibrous capsule, the bursa between tendons of the semimembranosus and semitendinosus, bursae deep to the tibial collateral ligament, the bursa superficial to the tibial collateral ligament, and the semimembranosus bursa. The lateral bursae consist of the bursa between the fibular collateral ligament and the tendon of the biceps femoris, the bursa between the fibular collateral ligament and the tendon of popliteus, the bursa between the lateral head of the gastrocnemius and joint capsule, and the bursa between the tendon of the popliteus and the lateral femoral condyle.[14]

Mechanisms of Knee Injuries

Due to the complex nature of the anatomy of the knee, injury to the joint is quite common as a result of both chronic stress and acute insult. This article examines the more common types of knee injuries that occur, describing the mechanisms required to cause these specific injuries. This article also explores how tears occur to the medial and lateral meniscus, anterior cruciate ligament, posterior cruciate ligament, medial cruciate ligament, and lateral cruciate ligament, as well as the causes of arthritic changes, chondromalacia, and bursitis.

Meniscal Tears

A tear to the menisci is caused by a combination of compression of the knee joint (such as during weight bearing) in the presence of a rotary force and flexion or extension, or in the absence of synchronous rotation during flexion or extension.[2,17] When the knee joint is compressed, the condyles of the femur and the tibial plateaus are brought closer together, which reduces the ability of the menisci to move freely during rotation and flexion or extension. Essentially, a portion of the menisci becomes trapped

Figure 7: Tearing of the medial collateral ligament as a result of a direct valgus force and external rotation*

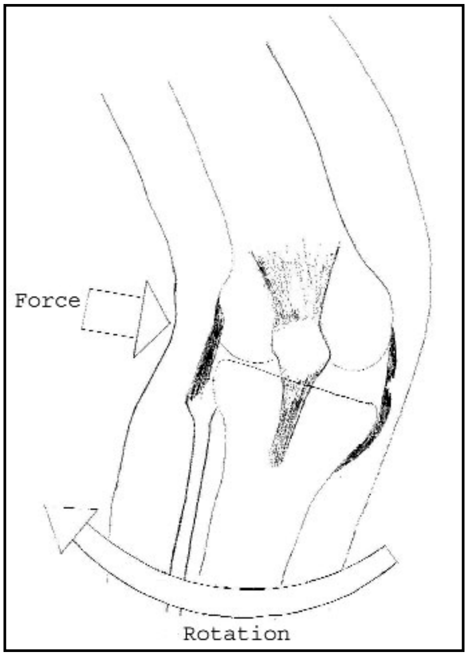
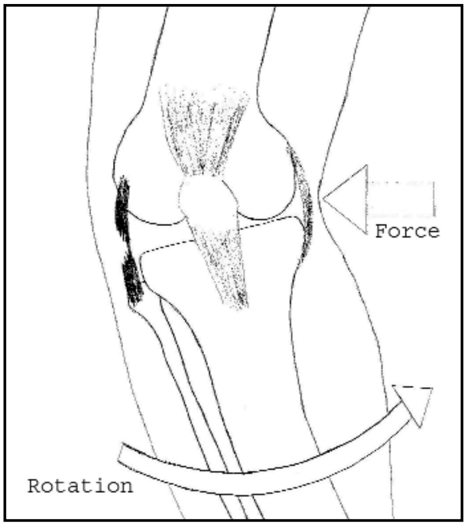


Figure 8: Tearing of the lateral collateral ligament as a result of a direct varus force and internal rotation*



and a tear results as a portion of the menisci moves while the trapped portion does not. It is important to note that rotation of the knee joint does not occur in full extension; therefore, a meniscal tear cannot occur in a position of full extension.[17] Also, it is very uncommon for both menisci to be torn in a single event. The second meniscal tear is usually the result of a joint that has had a history of internal derangement due to relaxation of either the joint capsule or ligaments and weakened quadriceps musculature.

Anterior Cruciate Ligament Rupture

Ruptures of the anterior cruciate ligament can occur due to rotation, abduction, posterior translation of the femur with respect to the tibia, hyperextension, or dislocation of the knee joint. The anterior cruciate ligament is most commonly ruptured during internal rotation of the tibia while the knee is flexed.[4] In order to achieve rupture of the anterior cruciate ligament due to abduction, the medial collateral ligament must first be ruptured. When the medial collateral ligament is ruptured due to abduction, the rupture of the anterior cruciate ligament is inevitable.[17]

Posterior Cruciate Ligament Rupture

Posterior cruciate ruptures are created when a posterior force is applied to the head of the tibia while the knee is in flexion.[17] Ruptures of the posterior cruciate ligament may also occur during both hyperflexion and hyperextension. Hyperflexion without coupled posterior translation of the tibia often results in an avulsion of the posterior cruciate ligament from the femur.[7] When ruptures of the posterior cruciate ligament occur as a result of hyperextension, first the anterior cruciate ligament is ruptured, followed by injury to the posterior capsule. Then, at 30 degrees of hyperextension, injury to the posterior cruciate ligament occurs; finally, injury to the poplitieal artery occurs at 50 degrees of hyperextension.[7]

Injury to the posterior cruciate ligament most frequently occurs as a result of motor vehicle accidents and has been referred to as "the dashboard injury." During a frontal collision, the occupants of the front seat travel forward and strike their knees on the dashboard. This forces the head of the tibia to move posteriorly and causes the posterior cruciate ligament to rupture.[7] Another common means of rupturing the posterior cruciate ligament is falling onto a flexed knee, which also drives the tibia posteriorly, rupturing the posterior cruciate ligament (Figure 6).[2]

Medial Collateral Ligament Rupture

Ruptures of the medial collateral ligament are caused by a direct valgus force applied to the knee, as well as by an external rotation of the knee joint (Figure 7).[2,4] A medial collateral ligament injury is usually more severe than a lateral collateral ligament injury because the medial collateral ligament is part of the joint capsule and is attached to the medial meniscus, while the lateral collateral ligament is not.[2,9]

Lateral Collateral Ligament Rupture

Ruptures of the lateral collateral ligament are uncommon; however, when they do occur, they are caused by a varus force applied to the knee joint (often coupled with internal rotation of the tibia) (Figure 8) or during complete dislocation of the knee.[2,17] Injury to the lateral collateral ligament is rarely an isolated injury and often is concomitant with stretching or rupturing of the lateral popliteal nerve.[17]

Knee Osteoarthritis

Osteoarthritis of the knee is a disease that is characterized by degeneration of the articular cartilage of the joint. Osteoarthritis is also referred to as osteoarthrosis and degenerative joint disease. The degeneration of articular cartilage leads to a loss of shock absorption, which in turn leads to trabecular micro-fractures. Subsequently, the subchondral bone begins to degenerate and osteophytes form at the joint margin.[19,18]

The cause of osteoarthritis is not well known; however, risk factors have been established and include age, gender, previous trauma to the joint, and possibly obesity. The prevalence of knee osteoarthritis increases with age because as cartilage ages, it undergoes changes that decrease its ability to withstand compression, putting more stress on the subchondral bone.[8,11]

Females seem to be more likely to get osteoarthritis than males, but males tend

Table 1: *Mechanisms & Types of Knee Injuries*

Injury	*Mechanism of Injury*	*How the Injury May Occur*
Torn Meniscus	combination of compression, rotation and flexion\extension, or absence of synchronous rotation during flexion\extension	twisting knee while walking due to unknowingly stepping in a ground depression
Ruptured ACL	rotation, abduction, posterior translation of the femur, hyperextension or dislocation	twisting knee upon landing after jumping or falling
Ruptured PCL	posterior translation of the tibia, hyperflexion or hyperextension	striking knee on dashboard or falling onto a flexed knee
Ruptured MCL	valgus force applied to the knee or external rotation	lateral side of pedestrian's knee struck by the bumper of a moving vehicle
Ruptured LCL	varus force applied to the knee or complete dislocation	blow to medial aspect of the knee; often concomitant with other knee injuries
Osteoarthritis	unknown; however, risk factors include age, gender, previous trauma, and possibly obesity	increased age, female gender, and being overweight
Chondromalacia	unknown, however it has been postulated that abnormal patellar tracking is a major etiological factor	abnormal patellar tracking secondary to knee injury which disrupts function of the vastus medialis
Bursitis	contact trauma, prolonged kneeling and repeated flexion/extension	striking knee on rigid surface, such as dashboard or ground

to get osteoarthritis at a younger age.[1,12] It has been suggested that males get osteoarthritis at a younger age due to the influence of trauma or occupation.[12]

Any damage to the joint cartilage, no matter how minimal, can lead to osteoarthritis. This is because cartilage has limited healing abilities due to poor vascularity. Once injured, the degeneration process of the joint cartilage begins and is difficult to halt or reverse.[19,11]

The increased body weight of obese individuals increases the stress placed on the cartilage in the joint and can become a contributing biomechanical factor for knee osteoarthritis.[12] Logically, increased loading stress will diminish the capacity for protection of the subchondral bone and injury to these structures is more likely, thus increasing the risk of osteoarthritis.

Knee Chondromalacia

Chondromalacia is the softening and deterioration of the articular cartilage on the posterior surface of the patella. The exact cause of chondromalacia is unknown; however, it has been postulated that abnormal patellar tracking is a major etiological factor.[13] Three stages of chondromalacia have been identified. Stage 1 involves the swelling and softening of the articular cartilage. Stage 2 involves the fissuring of the softened articular cartilage, and stage 3 involves deformation of the surface of the articular cartilage caused by fragmentation.[3]

Bursitis

Bursitis of the knee is the inflammation of one or more of the numerous bursae that surround the knee joint. Bursitis can be acute, chronic, or recurrent.[2] Most commonly, the bursae in the anterior group become inflamed. Common mechanisms of knee bursitis include contact trauma, prolonged kneeling, and repeated flexion or extension of the knee.

Summary

Although the knee, at first glance, appears to be a relatively simple hinge joint that merely moves in flexion and extension, trauma to the knee can occur in many different manners, some of which are summarized in Table 1. However, in order to damage one of the specific structures of the knee, the mechanism required to injure that structure must be present or injury cannot result. Meniscal tears require compression, rotation and flexion, or extension. Ruptures of the anterior cruciate ligament occur as a result of rotation, abduction, posterior translation of the femur with respect to the tibia, hyperextension, or dislocation of the knee joint. Ruptures of the posterior cruciate ligament occur as a result of posterior translation of the tibia while the knee is flexed from hyperextension or hyperflexion. The medial collateral ligament will rupture as a result of a valgus force or external rotation. The lateral collateral ligament will rupture as a result of a varus force or complete dislocation of the knee. Bursitis of the knee is often a result of direct impact, prolonged kneeling, or repeated flexion or extension of the knee. While the causes of osteoarthritis and chondromalacia are not known, we do know there are risk factors that increase the likelihood of developing these problems. The risk factors for osteoarthritis include age, gender, previous trauma, and obesity, while abnormal patellar tracking is the risk factor for chondromalacia.

As can be seen, there is no doubt about the true complexity of the knee joint, the major processes that occur as people walk, sit, stand, run, and jump, and the debilitating injuries that can occur when external and internal forces cause the structures of the knee to exceed their physical limits.

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*Figures 6, 7, and 8 are based on diagrams originally printed in Arnhein DD, Prentice WE. *Principles of Athletic Training.* 8th ed. St. Louis, MO: Mosby Year Book;1993.

About the Authors

Matthew Donohoe holds a bachelor's degree in kinesiology with an emphasis in athletic training, and a master's degree in physical education with an emphasis in biomechanics and athletic training. He has also been certified as an athletic trainer by the National Athletic Trainers Association. Donohoe's studies and professional experience have focused on accident reconstruction, biomechanics, athletic training, and injury rehabilitation. He has assisted in research projects at San Diego State University's Biomechanics Lab and has developed and carried out the protocol for research investigations on osteoarthritis knee bracing. Donohoe lectures on biomechanics as it relates to low-speed automobile accidents and daily life activities, and has carried out research on forces generated by sporting activities and activities of daily living. Currently Donohoe utilizes his knowledge of accident reconstruction, biomechanics, and the mechanics of injury at the Institute of Risk & Safety Analyses to determine the potential for injury in a given accident.

Helen Aslanian obtained a bachelor's degree in physics from the University of California, Los Angeles (UCLA) in 2001 and is currently working on a master's degree in engineering at UCLA. Her experience includes an internship at Boeing's Electron Dynamics Division, and her professional responsibilities have included assessing and studying products and engineering laboratory processes to create a detailed, web-interface database.

As an undergraduate student at UCLA, Aslanian co-authored and presented papers based on her research on solid-state physics. Her research included laboratory work on, and analysis of, superconducting materials at the National High Magnetic Field Laboratory in Florida. Today Aslanian applies her understanding of a broad range of physics and her background in analysis and problem solving to the field of accident reconstruction at the Institute of Risk & Safety Analyses.

Dr. Kenneth Solomon obtained a bachelor's, master's, and doctorate degree in engineering and a postdoctorate degree in risk benefit assessment from UCLA. He also holds a professional engineering license. Dr. Solomon's studies are limited primarily to accident reconstruction, biomechanics, and risk-benefit assessment, as demonstrated by his 29 years of independent research; his more than 200 internationally distributed publications, reports, and presentations; the three books he co-authored; and his journal guest editorships. In December of 1998 and after over 22 years of service, he retired as Senior Scientist with the RAND Corporation. He was on the faculty at the RAND Graduate School for 18 years and has taught as an adjunct faculty member at UCLA, the University of South Carolina, the Naval Post-Graduate School, and George Mason University. Dr. Solomon is a reserve deputy level IV with the Orange County Sheriff-Coroner's Department. He is also Commissioner of the Policing Commission for the City of Calabasas. He has published studies on transportation accidents (involving automobiles, trucks, motorcycles, and bicycles), industrial and recreational accidents (involving pressure vessels; rotating machinery; forklifts and cranes; exercise, gym, and recreational equipment; swimming pools; and manufacturing and punch presses), slip-and-fall and trip-and-fall accidents, and the adequacy of warnings.

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