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A Recreational Runner’s Guide to Knee Pain

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Introduction:

The most common pain runners experience is associated with the knee joint. However, if you do an Internet search for "knee pain," there is no telling what will come up or how accurate the information might be. On the other hand, scouring research articles for more fact-based recommendations can be time consuming and confusing. With this guide, the research has been done for you and a list of references is readily available at the end of the document if you want to look further into a specific topic. You shouldn't need a degree in exercise science or anatomy to have an idea of what it going on with your knee pain. The goal of this guide is to provide the tools necessary to learn more about your knee pain and some strategies for overcoming that pain in a single, easy to navigate format.

How This Guide Works

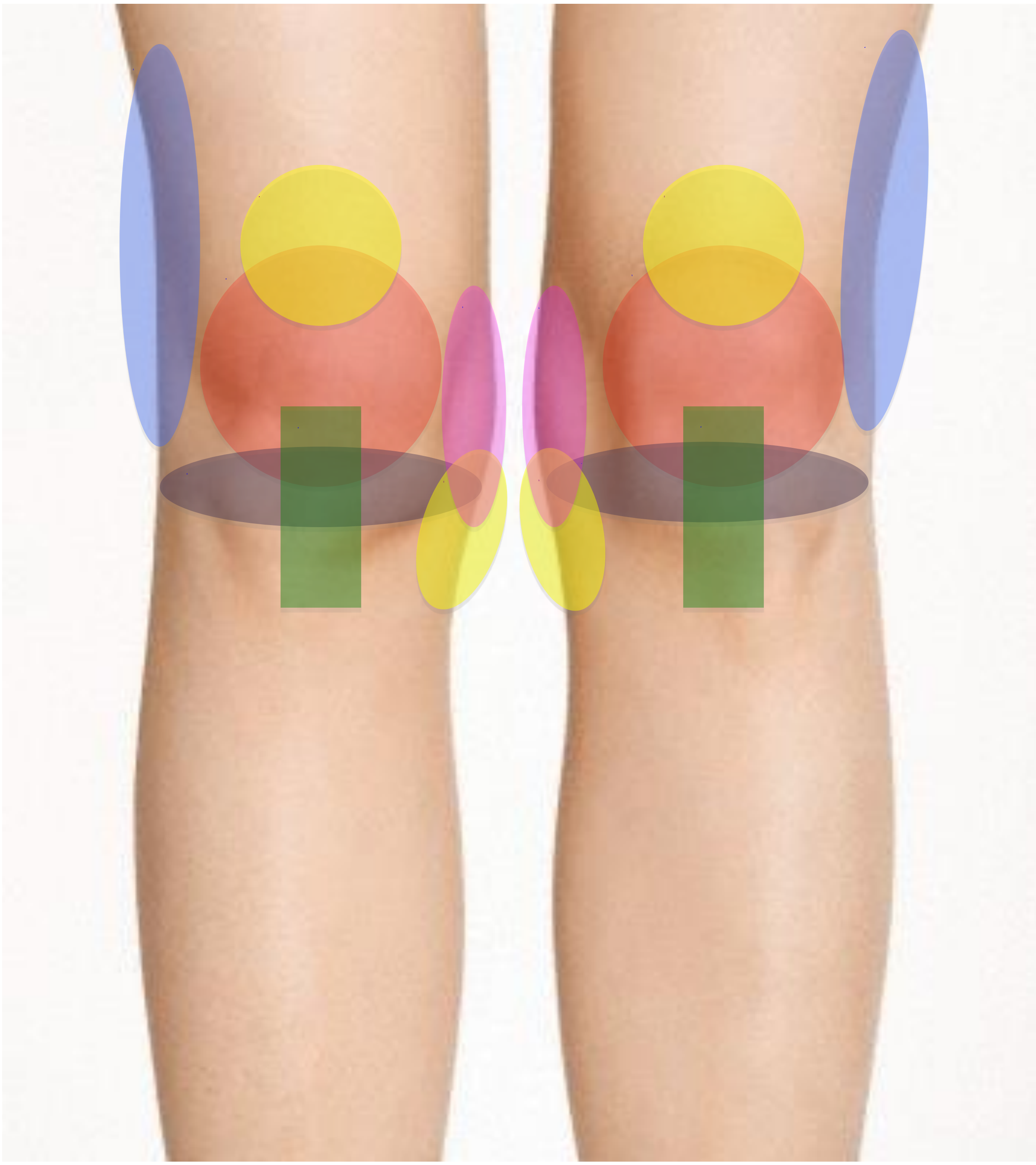
This guide is meant to be interactive, so you don't need to read through every page to get to the information that pertains to your personal knee pain. On the next page, you can click the location of your knee pain on the image and the guide will take you to the most likely possible cause of that pain. From that point, continue following the links to read about some possible interventions. Also provided in this guide are sections describing directional terms, movement terms, the anatomy of the knee, and the biomechanics of running as readily available references for any questions regarding the workings of the knee.

Author's Note:

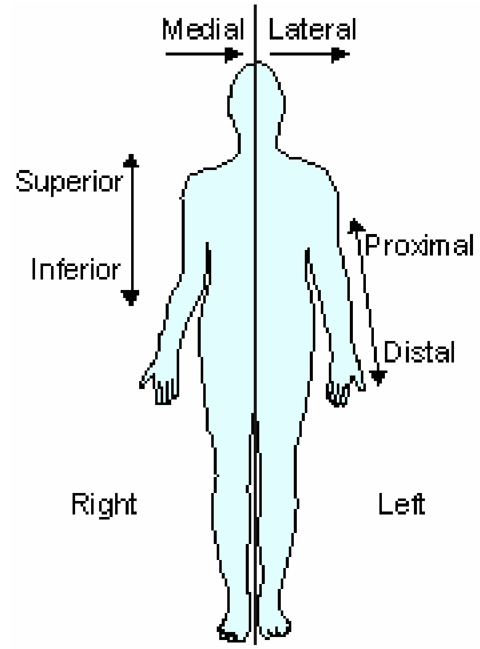
This guide should not be used as a diagnostic tool. The author is an undergraduate exercise science student and not a medical professional. The purpose of this guide is to present the recreational runner options and information to help better understand what might be causing their knee pain and some interventions that may help alleviate that pain. If your knee pain is severe or gets worse, make an appointment with a medical professional.

Locate Your Knee Pain

Click the location of your knee pain in the image below or follow this link for general knee pain. If your knee pain is located in a section where the colors overlap, pick the color area that most resembles the full location of your knee pain and click on just a single color. You can always come back to this page and follow the other overlapping color after you finish reading your first choice.



Directional Terms:



Medial: Used to describe a structure as being closer to the midline than another structure.

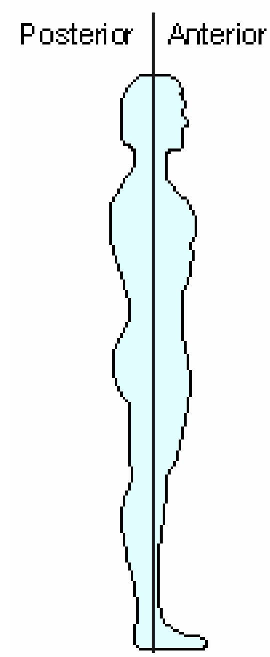
Lateral: Structures located farther to the sides of the midline as compared to other structures.

Superior: A way to describe a structure as above another structure.

Inferior: A way to describe a structure as below another structure.

Proximal: Used to describe a structure on a limb that is located closer the point of attachment than another structure

Distal: Used to describe a structure on a limb that is located further from the point of attachment than another structure.



Anterior: A structure located more towards the front of the body than another structure.

Posterior: A structure located more towards the back side of the body than another structure.

Deep: Used to describe a structure as located farther within the body than another structure.

Superficial: A structure that is closer to the surface of the skin than another structure.

Frontal Plane: This plane splits the body into anterior and posterior sections. Motion in the frontal plane typically happens in the medial-lateral directions.

Sagittal Plane: This plane divides the body into right and left segments.

Transverse Plane: This plane splits the body into superior and inferior segments. Motion in the transverse plane is typically rotational.

The Knee Joint:

An Overview:

The knee joint is an integral part of leg movement. While the knee is considered a hinge joint, which typically produces only a single plane of movement, the knee also allows some movement in a second plane. The main movements of the knee joint are flexion and extension, but small degrees of internal and external rotation can be observed. This section will provide definition and description of the major components of the knee joint as well as other structures and motions that may be related to the development of knee pain.

Movement Terms:

Flexion: The decrease in angle between two bones. Flexion in the knee is commonly called bending and this movement occurs in the sagittal plane. The normal degree of flexion for the knee joint is about 150 degrees.

Extension: The increase in angle between two bones. In the knee, extension is commonly known as straightening the leg. The knee can normally extend to a completely straight position, or 0 degrees of flexion. However, some knees have the ability to hyperextend up to 10 degrees.

Internal Rotation: This is rotation of the bone in the [transverse plane] in the [medial] direction. In the knee, there is a small degree of internal rotation that occurs, but the motion can only occur when the knee is flexed at least 30 degrees. The normal degree of internal rotation for the knee joint is about 30 degrees.

External Rotation: This is rotation of the bone in the [transverse plane] in the [lateral] direction. The knee can undergo a small degree of external rotation, but the motion can only occur when the knee is flexed at least 30 degrees. The normal degree of external rotation for the knee joint is about 45 degrees.

Adduction: This is motion of a body part toward the midline. An easy way to remember this is to think of the word as "add"uction, so the body part is being added to the midline of the body. This is a movement in the [frontal plane], and while the knee does not undergo adduction, studies have shown that adduction of the hip may be important in the cause of knee pain.

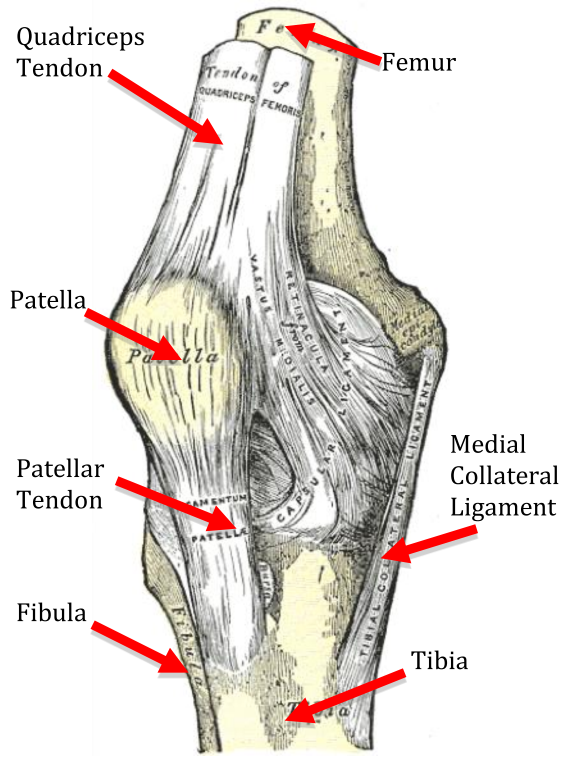
Abduction: This is the movement of a body part away from the midline. Think of this word as "abduct"ion, so the body part is being abducted, or taken away, from the body's midline. This is the opposing motion to adduction and also occurs in the [frontal plane]. Hip abduction is an important factor in the development of knee pain and is the motion of the leg laterally, away from the other leg.

Bones:

The bones that come together to form the knee joint include the femur, patella, tibia, and fibula. Each bone either directly articulates in the joint and/or provides important attachment points for ligaments and the tendons of muscles.

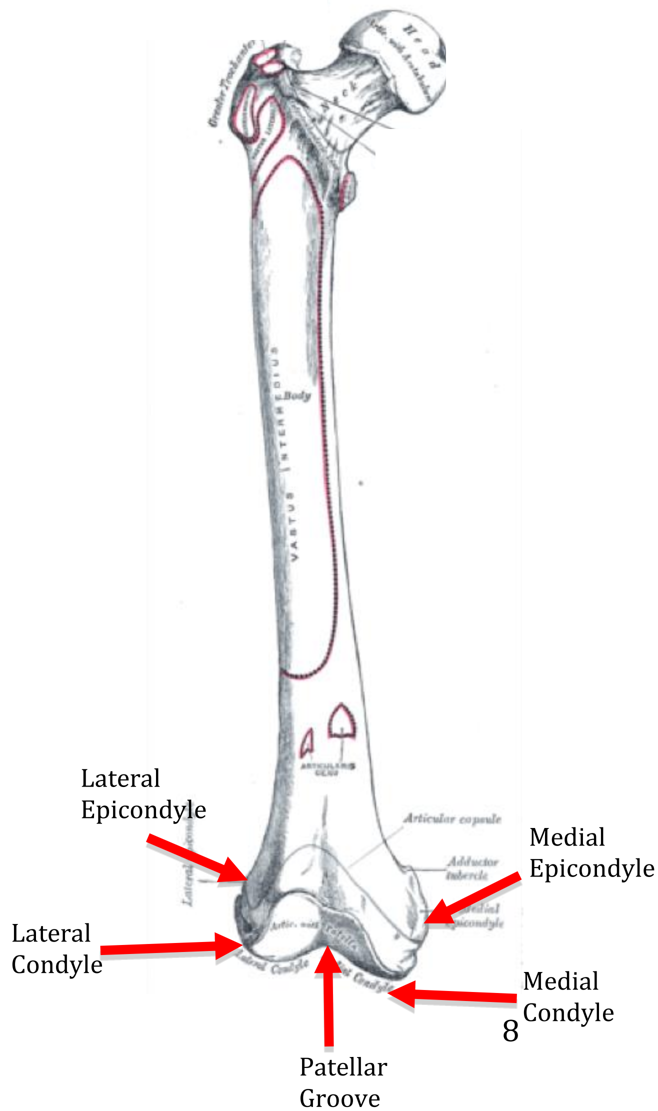
Femur:

The femur is the longest bone in the human body and is located in the thigh portion of the leg between the hip and knee joints. The end of the femur farthest from the point of attachment at the hip, also called the distal end, has a number of key structures that are important to the knee joint. On the very end of the femur are two enlarged boney structures called the medial condyle and the lateral condyle. Because of the position of femur within the thigh, the medial condyle bears more weight than the lateral condyle and thus is slightly larger to accommodate for the differences in forces. These condyles are covered cartilage to reduce friction where they articulate with the medial and lateral condyles of the tibia. This area where articulation occurs is known as the tibiofemoral surface. Located just superiorly to the medial and lateral condyles of the femur are the medial and lateral epicondyles of the femur. These are boney protrusions that are important attachment sites for both muscles and ligaments. The patellar groove is located on the anterior portion of the distal femur between the medial and lateral condyles. This structure, also called the patellofemoral surface, allows the patella to glide as the knee joint flexes and extends. On the posterior side of the distal femur between the medial and lateral condyles is a groove called the intercondylar fossa. The internal ligaments that hold the knee joint together, the anterior cruciate ligament and the posterior cruciate ligament, are located within this space.



Right Knee Joint Anatomy (Above)

Right Femur (Below)



Patella:

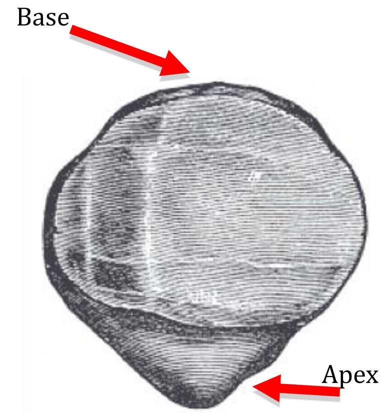
The patella, also commonly known as the kneecap, is an almost triangular shaped bone that lies within the quadriceps tendon. This bone articulates with the patellofemoral surface of femur. The broader base of the patella is positioned superiorly to the pointed apex.

Tibia:

The tibia, the larger of the two bones that make up the lower leg, is located medially and bears the majority of body weight as opposed to its smaller partner, the fibula. The end of the tibia nearest to the knee joint is referred to as the proximal end. The tibia, like the femur, has a medial condyle and a lateral condyle. Unsurprisingly, the lateral condyle of the tibia articulates with the lateral condyle of the femur and the medial condyle of the tibia articulates with the medial condyle of the femur. A very important attachment site on the tibia is the tibial tuberosity. This structure is a large bump located on the anterior side of the tibia below the medial and lateral condyles. When in a kneeling position, this structure that the majority of a persons weight acts through and can be easily felt.

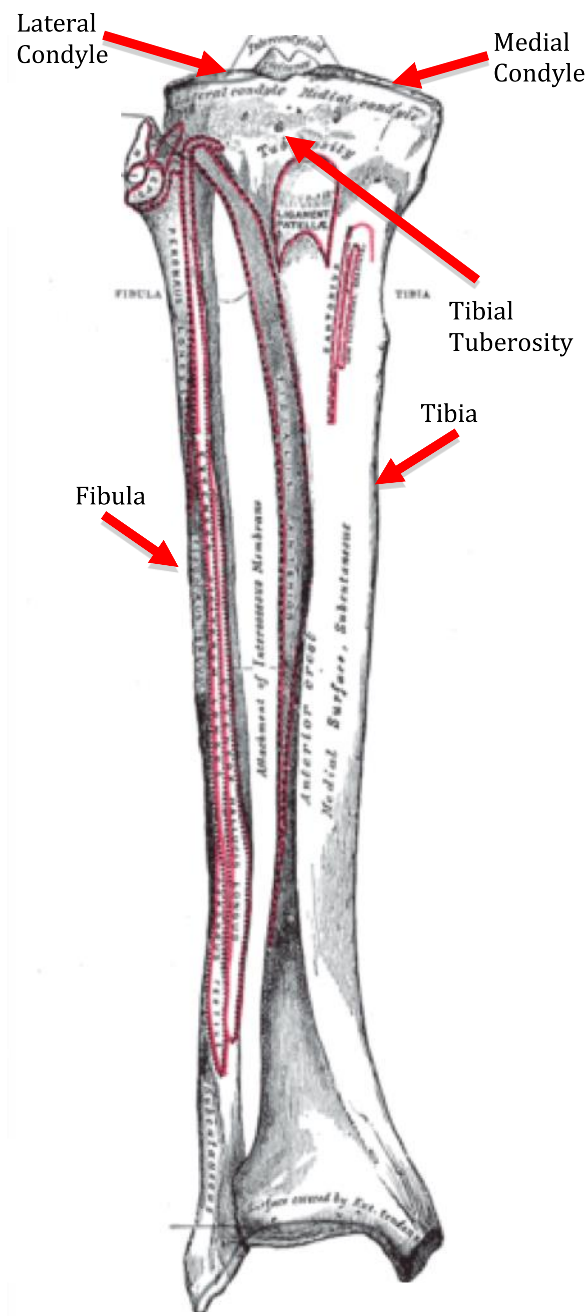
Fibula:

The fibula is the smaller of the two bones that make up the lower leg and is located laterally. Though it does not directly articulate with the knee joint, the head of the fibula is an attachment point for both muscles and ligaments important to the knee.



Posterior Aspect of the Patella (Above)

Right Articulated Tibia and Fibula (Below)



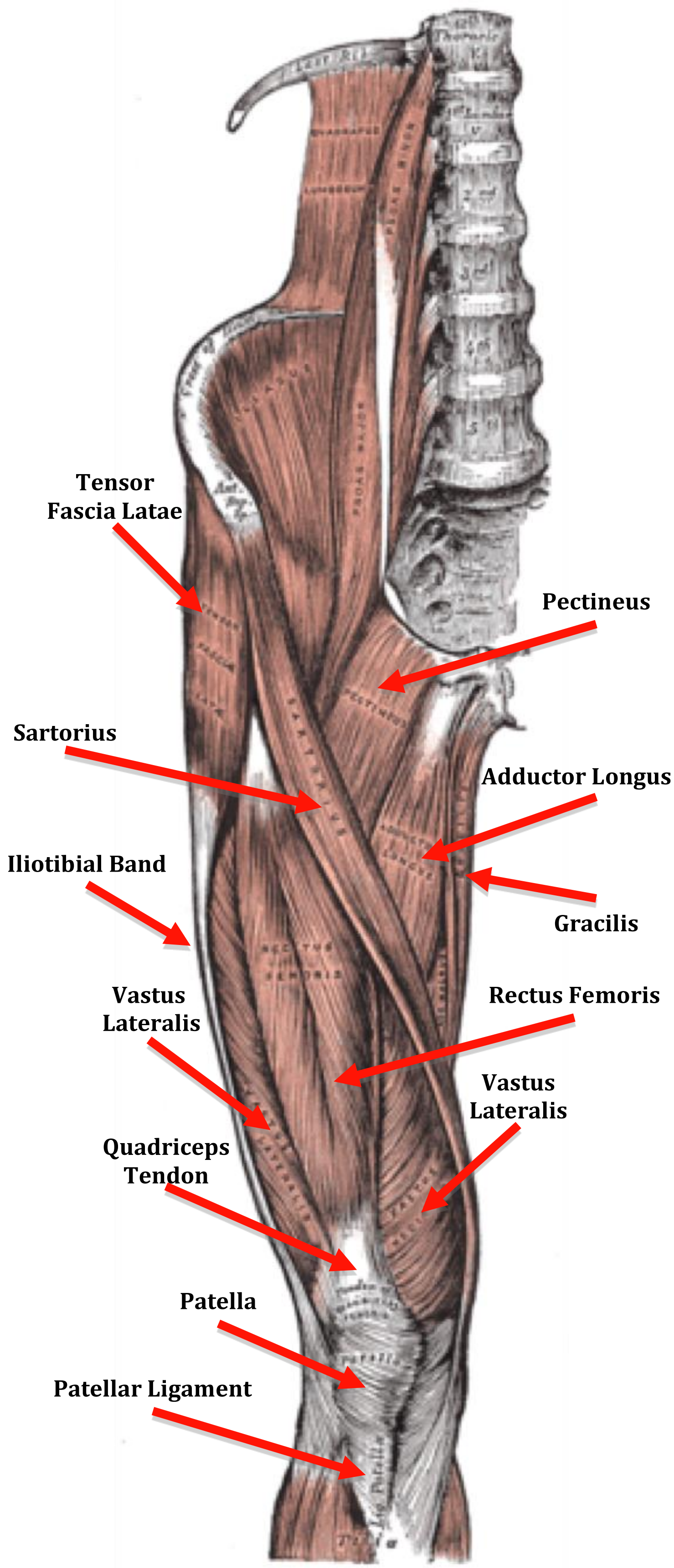
Muscles:

Anterior

Quadriceps:

The quadriceps group of muscles is responsible for extension of the knee joint. The four individual muscles are listed below. The tendons of each of these muscles connect through the quadriceps tendon, attach to the patella, and continue down as the patellar ligament, in some cases also referred to as the patellar tendon, to attach on to the tibial tuberosity.

- Rectus Femoris: This is the most superficial muscle of the quadriceps group and is located between the vastus medialis and the vastus lateralis. In addition to the knee extension motion produced by all the muscles of the quadriceps group, the rectus femoris also aids in flexion of the hip.
- Vastus Medialis: This is the most medial muscle of the quadriceps group.
- Vastus Lateralis: This is the most lateral of the quadriceps group.
- Vastus Intermedius: This muscle is located deep to the rectus femoris and is not shown in the diagram.



Lateral

Hip Abductors:

These are the muscles that abduct the hip. The hip abductors are all considered to be in the lateral compartments of the thigh or gluteal regions with the exception of the sartorius, which is an anterior muscle.

- Gluteus Medius: The gluteus medius is located deep to the gluteus maximus, or the muscle that most consider the main "butt muscle." Along with hip abduction, the gluteus medius also produces internal rotation, external rotation, flexion, and extension of the hip, depending on the position of thigh compared to the pelvis.
- Gluteus Minimus: This muscle is deep to the gluteus medius and attaches to the flat portion of the posterior-lateral pelvis. In addition to hip abduction, the gluteus minimus can also produce internal rotation and flexion of the hip.
- Tensor Fasciae Latae: This is a small muscle on the anterior-lateral portion of the upper thigh. While the muscle body itself is small, it is connected to a long, tough band of connective tissue called the iliotibial band. The tensor fasciae latae also produces flexion and internal rotation at the hip joint in addition to abduction.
- Sartorius: The sartorius, while an anterior muscle and not a lateral one, for our purposes fits best with the hip abductor category. The sartorius is a long, thin muscle that originates from the lateral pelvis and curves down over the anterior thigh to insert on the medial tibia. In addition to hip abduction, the sartorius also produces flexion of the hip, external rotation of the hip, and flexion of the knee.

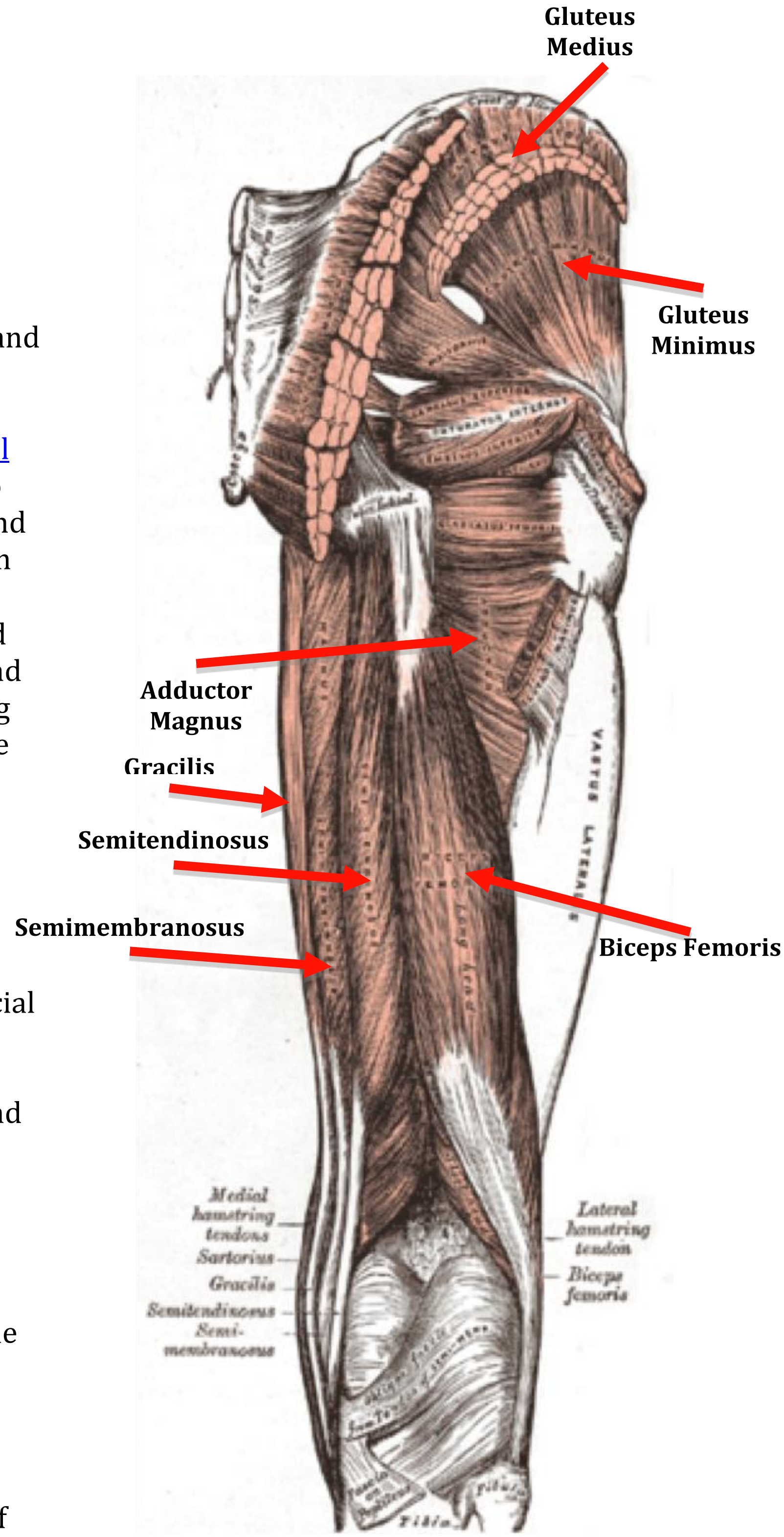
Medial

Hip Adductors:

These five muscles are responsible for adducting the hip.

- Pectineus: This is a short thick muscle on the superior, anterior-medial portion of the thigh. The pectineus also produces flexion and external rotation of the hip in addition to adduction.
- Adductor Longus: This muscle is located on the superior, medial portion of the thigh. This is a relatively superficial muscle.
- Adductor Brevis: This muscle is located deep to the adductor longus. It is not labeled in the diagram.
- Adductor Magnus: This muscle is the largest of the adductor muscles. It is a large, deep, medial fan shaped muscles that attached to the entire length of the femur. The labeled adductor magnus visible in the diagram is only a small portion of the muscle and the rest is located deep to the hamstring muscles. The adductor magnus is also partly responsible for hip extension.
- Gracilis: This is a long, thin muscle that runs the length of the medial thigh. In addition to hip adduction, the gracilis also helps produce hip internal rotation, slight hip flexion, and weak flexion at the knee.

<u>Posterior</u>



Hamstrings:

All three of the hamstrings muscles are responsible for producing flexion at the knee and extension at the hip.

- Biceps Femoris: This is the most lateral muscle of the hamstrings group. It also produces external rotation of the hip and external rotation of the knee in addition to knee flexion and hip extension.
- Semitendinosus: This muscle is located superficial to the semimembranosus and just medial to the biceps femoris. Along with knee flexion and hip extension, the semitendinosus also produces hip internal rotation and knee internal rotation.
- Semimembranosus: This muscle is located deep to the semitendinosus. However, the semimembranosus is broader and can be seen in the superficial image on either side of the semitendinosus. This muscle also produces internal rotation of the hip and knee, much the same as the semitendinosus.

Other Knee Flexors:

While the hamstrings are primarily responsible for knee flexion, the two muscles listed below also play a part.

- Gastrocnemius: The gastrocnemius is large muscle that covers the majority of the posterior lower leg. This muscle is commonly known as the "calf muscle."
- Popliteus: This muscle is located deep to the gastrocnemius on the posterior side. The popliteus crosses from the lateral femoral condyle to the upper, medial surface of the tibia. In addition to knee flexion, the popliteus also aids in internal rotation of the knee.

<u>**Connective Tissue:**</u>

Ligaments:

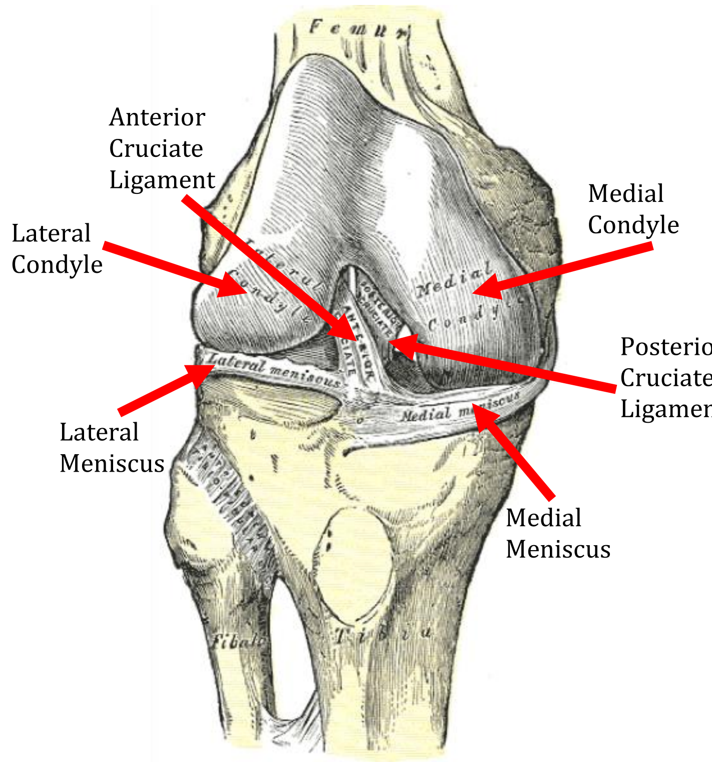
Ligaments are a type of connective tissue that attaches bone to bone. There are four main ligaments that help to give the knee joint its stability. The anterior cruciate ligament (ACL) and the posterior cruciate ligament (PCL) make a cross inside the joint capsule of the knee between the femur and tibia, deep to the patella. The cruciate ligaments help to keep the tibia from translating too far forward or backward as compared to the femur. The remaining ligaments are the medial collateral ligament (MCL) and the lateral collateral ligament (LCL). The collateral ligaments are located on either side of the knee joint on the outside of the joint capsule. The MCL attaches the femur to the tibia and the LCL attaches the femur to the fibula. The collateral ligaments work together to ensure the knee joint does not perform frontal plane movements.

Menisci:

The medial and lateral menisci are disks of connective tissue that help to absorb shock between the femoral condyles and the tibial condyles. These disks of connective tissue are thicker near their edges with a thinner middle.

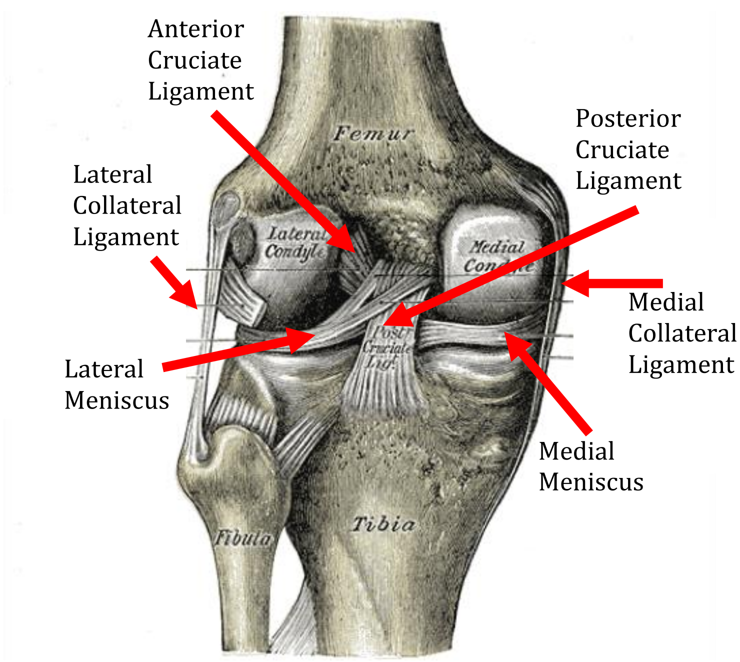
The Iliotibial Band:

The iliotibial (IT) band is a thick band of connective tissue that originates near the hip, runs along the outer leg, crosses over the lateral aspect of the knee joint, and inserts on the lateral epicondyle of the tibia.



Anterior Right Knee Joint with Patella and Joint Capsule Removed (Above)

Posterior Right Knee Joint (Below)



Other Associated Structures:

Bursae:

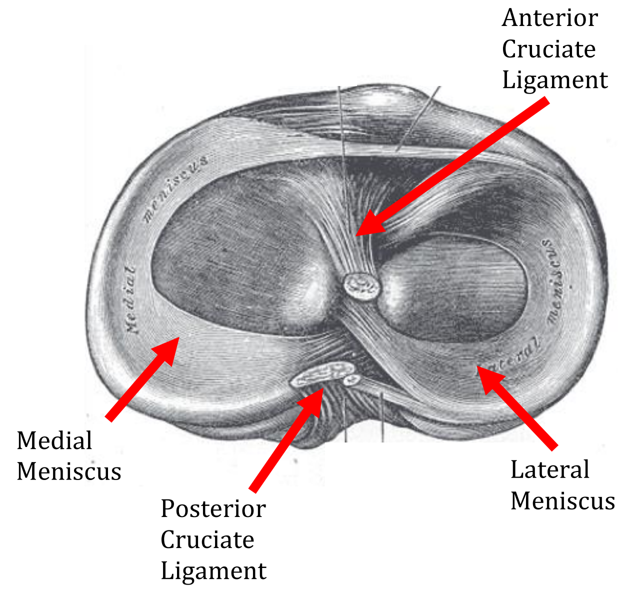
Bursae are fluid filled sacs that help to reduce friction of sliding tendons and ligaments around joints. The knee joint has numerous bursae, but those more likely to become an issue with running are the suprapatellar bursa and the pes anserine bursa. The suprapatellar bursa is located just superior to the patella and deep to the quadriceps tendon. This bursa helps to reduce the friction between the quadriceps tendon and the femur. The pes anserine bursa lies between the MCL and the more superficial tendons of the semitendinosus, sartorius, and gracilis. This area can be found on the medial aspect of the knee about 2 inches inferior to the joint line.

Joint Capsule of the Knee:

The joint capsule give the knee added structure and stability. It is made up of ligamentous tissue that surrounds the knee on all sides. The inner lining of the joint capsule is made up of a synovial membrane. This membrane secretes a thick fluid called synovial fluid that reduces friction between the structures that make up the knee joint. The ACL, PCL, and menisci are located within the space created by the joint capsule. The LCL and MCL are located outside of the joint capsule and provide added strength and support to the capsule as well as the entire knee joint.

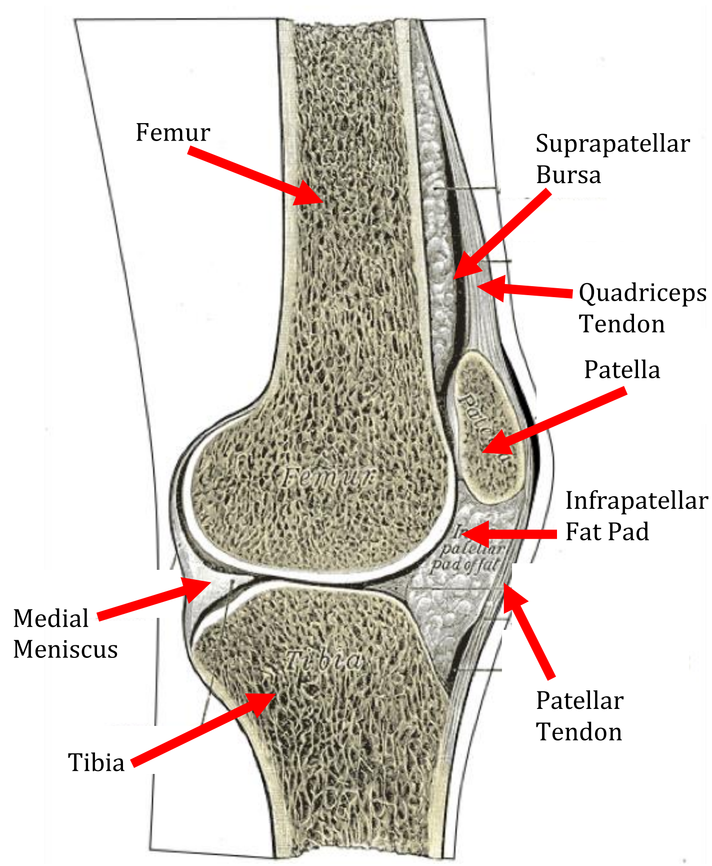
Infrapatellar Fat Pad:

The infrapatellar fat pad is a cushion of fat that lies under deep and slightly inferior to the patella. It helps to reduce impact forces between the patella and the femoral condyles.



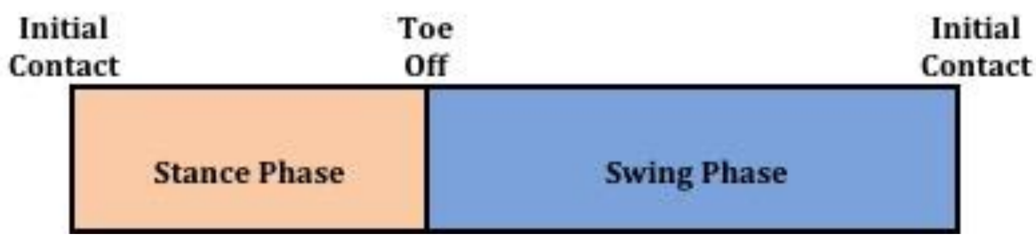
Superior View of Tibia with Menisci and Cruciate Ligaments (Above)

Sagittal Cross-Section of Knee Joint (Below)

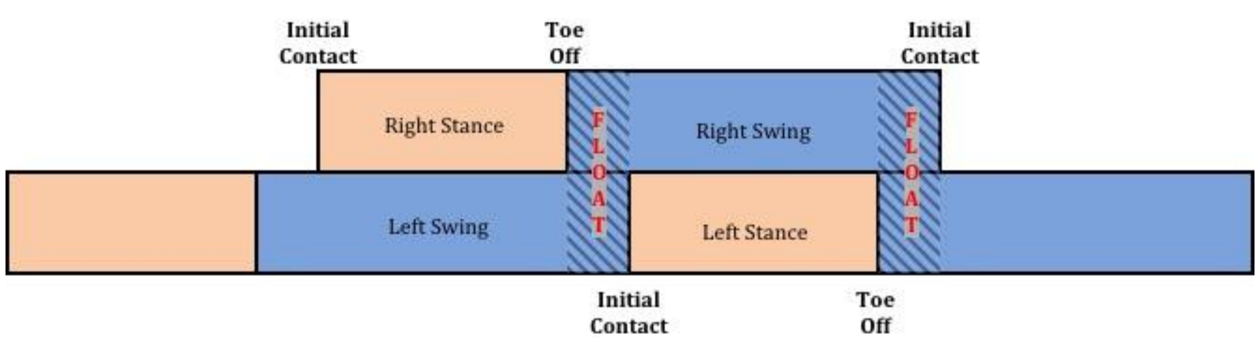


Biomechanics of Running:

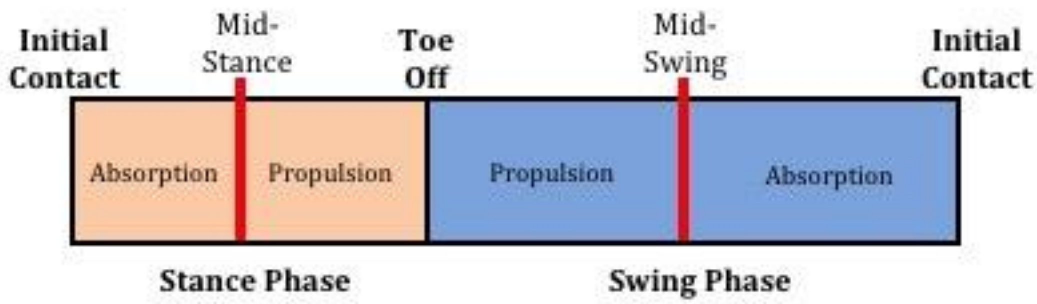
When talking about running, it is important to understand the gait cycle. A single gait cycle, also known as a stride, focuses on the motion of one leg from the initial contact with the ground through the swing until the foot contacts the ground again. A full gait cycle can be broken down into the stance phase and the swing phase. The stance phase occurs first from the point of initial contact to the point of toe off. The swing phase is the second part of the gait cycle and occurs from the point of toe off to the point when the foot comes back into contact with the ground.



It is also important to note that while walking and running are similar motions, the gait cycles are slightly different. The main distinguishing factor between a walking and a running gait cycle is the percentage of the cycle spent in each phase. The walk is characterized by a greater than 50% time spent in the stance phase. This distribution of time allows for a period of double limb support in which both feet are in contact with the ground. The transition between a walk and a run occurs when greater than 50% the gait cycle is spent in the swing phase. Because of this difference, instead of a period of double limb support, running involves brief periods of “float” in which neither foot is in contact with the ground. The diagram below provides a graphic representation of how the gait cycles of the right and left leg overlap to allow for float.



The stance and the swing phase can both be subdivided into absorption periods and propulsion periods. These periods are marked between initial contact, mid-stance, toe off, mid-swing, and the initial contact of the next gait cycle. Specific action occurs at the different joint levels for each of these subdivisions of the running gait cycle. For our purposes, we will narrow the focus to the knee joint. The diagram provides a visual description of how the running gait cycle is divided into the different phases and subdivisions.



Stance Subdivisions:

Absorption:

The first portion of the stance phase is the absorption period. This period, also known as initial stance, occurs between the point of initial contact and the point of mid-stance. For the majority of runners, initial contact is made with the rearfoot or heel strike, though runners may also employ a midfoot or forefoot strike pattern. Mid-stance is the point at which the foot is flat and fully in contact with the ground. During this period, the knee undergoes about 45 degrees of flexion (Buschbacher, Prahlow, & Dave, 2009) to absorb the force of the initial contact.

Propulsion:

The propulsion subdivision of the stance phase occurs from the point of mid-stance to toe-off. The toe-off marks the transition between stance phase and swing phase as the foot moves from contact with the ground to noncontact. During this portion of stance, the knee ends moves into almost complete extension (Buschbacher et al., 2009) to generate power and propel the runner forward.

Swing Subdivisions:

Propulsion:

The leg continues to generate power through the first portion of the swing phase. The propulsion subdivision of the swing phase occurs from the point of toe-off to mid-swing. During the propulsion subphase of swing, the knee undergoes movement from almost complete extension to about 90 degrees of flexion (Buschbacher et al., 2009). Precise values for maximum knee flexion during this subphase will vary because, in general, knee flexion increases as speed increase. Mid-swing occurs at the point where knee flexion transitions to knee extension, signifying the end of the power generation.

Absorption

The final subphase of the running gait cycle is the absorption phase of swing. This occurs from the point of mid-swing to the point of initial contact for the next gait cycle. During this subphase, the knee extends to absorb some of the power generated during the propulsion subphases in order to decelerate the swing leg and prepare the body for impact with the ground.

Possible Causes of Pain

General Knee Pain:

- Description of Symptoms:
  - While running, you may experience any number of symptoms from a dull ache to a throbbing sensation of the knee in general. This may be the start of one the conditions mentioned later in this guide.

- Possible Causes:
  - A major risk of injury to the knee is associated with high joint loading forces. Large impact forces during a running stride are transferred through the body and place those forces translate into high stress and loading forces on the knee joint and the associated structures. Consistent high impact forces can result in damage to the bones, muscles, connective tissues, and other structures of the knee over time. Weakness in the muscles of the lower body can also play a part in general knee pain and can lead to many of the other conditions discussed later in more detail. It may be beneficial to proactively alleviate joint stress and strengthen muscles of the lower body before your pain becomes a more serious condition.

- Possible Interventions:
  - Strength Training
  - Decrease Stride Length
  - Increase Stride Rate
  - Footwear
  - Foot Strike Pattern
  - Forward Trunk Posture

Patellofemoral Pain Syndrome (PFPS):

- What is it?
  - PFPS is the most common cause of knee pain in runners. This is an overuse injury that tends to have a higher frequency in female runners than in males.

- Description of Symptoms:
  - Pain associated with PFPS is in the anterior knee region, around and deep to the patella. Pain is generally described as diffuse or throbbing pain that is exacerbated by exercise. Symptoms are also associated with climbing or descending stairs, completing squats, and/or sitting for extended periods of time with the knees flexed. A grinding sensation of the patella, stiffness, or a sense of giving way may also accompany PFPS knee pain.

- Possible Causes:
  - A specific cause of PFPS is unknown, but research has shown multiple factors can play a role. Muscle weakness is commonly cited at the main cause of PFPS, especially an imbalance between the vastus medialis (VMO) and the vastus lateralis (VL) of the quadriceps. This imbalance can cause patellar maltracking because the stronger VL pulls the patella more forcefully in the lateral direction. Hip abductor weakness has also shown to have an association with PFPS, which causes over adduction at the hip. This occurs because the hip abductor muscles do not have the strength to oppose the stronger hip adductor muscles, causing valgus, or medially directed, stress at the knee joint that can contribute to patellar maltracking. The pain associated with PFPS may also stem from the degeneration of the cartilage on the underside of the patella due repetitive poor patellar tracking. This degeneration, also known as chondromalacia, is sometimes categorized as a separate condition from PFPS, but the symptoms are indistinguishable without medical evaluation. Another biomechanical factor associated with PFPS is over pronation, or inward rolling, of the foot. Some level of pronation is normal, but excessive pronation can cause tibial internal rotation and valgus stress, which are both associated with patellar maltracking. Apart from factors that cause maltracking, high patellar joint forces are also associated with PFPS. Recent research has shown that running style can affect patellar joint reaction forces and thus the pain felt during running activities. Some of these factors that increase joint reaction forces are an increased stride length, a decreased stride rate, a hard rearfoot strike, and an overly upright trunk posture.

- Possible Interventions:
  - Evaluate Training Program
  - Strength Training
  - Footwear
  - Orthotics
  - Increase Stride Rate
  - Decrease Stride Length
  - Forward Trunk Posture
  - NSAIDS
  - Patellar Bracing

Iliotibial Band Syndrome (ITBS):

- What is it?
  - ITBS is the second most common knee injury, after patellofemoral pain syndrome, associated with runners. This in an inflammatory condition of the IT band generally caused by overuse that results in pain of the lateral knee.

- Description of Symptoms:
  - Sharp or burning pain on the lateral aspect of the knee. This pain may extend into the thigh and/or hip. Generally the pain associated with ITBS will flare up with exercise and lessen with rest. This injury may also cause point tenderness or slight swelling of the lateral knee where the IT band crosses over the lateral femoral condyle.

- Possible Causes:
  - In runners, ITBS is most commonly caused by overuse. Because of the positioning of the IT band over the lateral femoral condyle, significant increases in running mileage or intensity over a short period of time can produce excess friction and thus irritation of the IT band. Studies have also shown that muscle weakness, especially in the hip abductors, has a high association with ITBS. Other factors that could play a part in developing ITBS are anatomical like differences in leg length and environmental like running on banked surfaces. Hip inflexibility and tightness of the connective tissue that makes up the IT band can also play a role in causing ITBS.

- Possible Interventions:
  - Evaluate Training Program
  - Increase Step Rate
  - Hip Abductor Strengthening
  - Flexibility Training
  - Ice Massage

Patellar Tendinitis:

- What is it?
  - Patellar tendinitis is also sometimes referred to as “Jumper’s Knee.” This is an inflammatory condition of the patellar tendon that results in pain just inferior to the patella.

- Description of Symptoms:
  - Patellar tendinitis results in pain inferior to the apex of the patella along the patellar tendon. The type of pain varies from a dull ache to a sharp pain, but is not usually associated with swelling or restrictions in normal movement.

- Possible Causes:
  - Patellar tendinitis is caused by inflammation or tearing of the patellar tendon. The inflammation in the patellar tendon is most often a result of repetitive motions like running or jumping over a long period of time. Significant increases in training volume over a short time period may also lead to overuse and result in patellar tendon inflammation. Environmental factors like running up hills have also been shown to put stress on the patellar tendon, possibly leading to patellar tendinitis over an extended time span.

- Possible Interventions:
  - Evaluate Training Program
  - Quadriceps Strengthening
  - Patellar Bracing
  - Ice
  - Pronation Control Orthotics

Bursitis:

- What is it?
    - Bursitis is the inflammation of the bursa. This condition can occur in any bursa in the body but with a focus on the knee joint and runners, suprapatellar bursitis and pes anserine bursitis are the most common forms.

- Description of Symptoms:
    - In general, bursitis causes painful swelling and due to inflammation of the bursa. In suprapatellar bursitis, pain and swelling is localized to the suprapatellar region, deep to the quadriceps tendon. Pes anserine bursitis also presents with swelling and point tenderness on the medial side of the knee and about 2 inches inferior to the joint line. There may also be an associated crackling, called crepitation, when palpating the area. Because of the pes anserine bursa's location between the MCL and the tendons of the semitendinosus, gracilis, and sartorius, contraction of these muscles through knee flexion or rotation may aggravate the pain symptoms.

- Possible Causes:
    - Bursitis can be caused by direct trauma to the bursa, but in runners the most common cause is overuse. The bursae are meant to reduce friction between tendons, ligaments, and boney structures during movement, but excessive friction over time can result in damage. The damage or irritation caused by the overuse results in inflammation and swelling of the bursa. Specifically, pes anserine bursitis may be associated with tight hamstrings due to the position of the bursa relative to the tendon of the semitendinosus. Also, excessive inward stress, called valgus stress, can put strain on those ligaments and tendons of the medial knee and can result in irritation of the pes anserine bursa. Pes anserine bursitis also has the environmental cause of running on a sloped terrain, such as a banked road. Running on a slope results in a running style similar to that of someone with a leg length discrepancy, another factor associative with pes anserine bursitis, in that one leg contacts the road in a higher position that the other.

- Possible Interventions:
    - Ice
    - NSAIDS
    - Rest
    - See a doctor

Plica Syndrome:

- What is it?
  - A plica is an infolding of the synovial membrane of the joint capsule that is may be left over from development as an embryo. It is estimated that about 50% of people have residual plica left over from their embryonic development. Plica syndrome generally occurs as a result of overuse that causes thickening or irritation of the plica. The most common structure involved in plica syndrome is called the medial plica, which is located along the medial wall of the joint capsule in the frontal plane from the suprapatellar area to the infrapatellar fat pad.

- Description of Symptoms:
  - Plica syndrome will cause pain and tenderness along the medial border of the knee joint. There may also be a snapping sensation as the knee goes through flexion and the irritated medial plica rubs against the femur.

- Possible Causes:
  - The medial plica will generally become inflamed due to repetitive bending and straightening movements. Overuse of the knee can put lead to friction between the medial plica and the femur that can cause irritation, inflammation, and thickening of the tissue over time.

- Possible Interventions:
  - Ice
  - NSAIDS
  - Patellar Bracing
  - Flexibility Training
  - Quadriceps Strengthening
  - See a Doctor, may recommend surgical plica removal

Infrapatellar Fat Pad Impingement:

- What is it?
  - This condition is sometimes also referred to as Hoffa's disease and it can cause a great deal of pain due to the vascular and nerve rich anatomy of the infrapatellar fat pad.

- Description of Symptoms:
  - Symptoms of infrapatellar fat pad impingement are similar to that of patellar tendinitis, but there are some distinct differences. Infrapatellar fat pad impingement may produce visible swelling around the apex of the patella to either side of the patellar tendon. Also, pain associated with an impinged infrapatellar fat pad can extend medially and laterally from the patellar tendon along the joint line, whereas pain from patellar tendinitis is generally localized to the patellar tendon. Pain from fat pad impingement may be worsened with running, jumping, extended periods of standing, or other positions where the knee is prone to hyperextension.

- Possible Causes:
  - In running, the most often cause of fat pad impingement is chronic irritation of the infrapatellar fat pad due to its location between the patellar tendon and the lateral femoral condyle. Repetitive straightening motions at the knee can cause excessive compression of the infrapatellar fat pad, which can cause irritation, inflammation, and sensitivity over time. This condition seems to be most common in individuals who exhibit higher than normal degrees of knee extension due to the additional compressive forces associated with hyperextension. Significant increases in training volume in an individual's running program may also lead to increased strain on the infrapatellar fat pad, which may result in the development of this condition. In addition to chronic irritation, a direct blow to the patella can also result in this condition, but is less likely in a running population due to the noncontact natural of the sport.

- Possible Interventions:
  - Evaluate Training Program
  - Rest
  - Ice
  - Patellar Bracing

Interventions:

Evaluate Training Program:

- Rest:
    - Recommendations for rest can sometimes be difficult for runners, who are generally a highly motivated and active population. However, rest is sometimes necessary to let the body heal, as the majority of the conditions described in this guide are related to overuse. Rest doesn't always have to mean a complete lack of training. Depending on the type and severity of your pain, rest can be a reduction in training volume or a switch lower impact aerobic activity like elliptical training until you find a reduction in knee pain.
- Progression:
    - Exercise and workout regimens can be judged by the F.I.T.T. principle. F.I.T.T. stands for Frequency, Intensity, Time, and Type and these represent the variables that can be adjusted to progress an exercise program to increase fitness. The American College of Sports Medicine (ACSM) recommends that for most adults, aerobic exercise should be performed at moderate intensity for at least 30 minutes on at least 5 days per week, at vigorous intensity for at least 20-25 minutes per day on at least 3 days per week, or a combination of moderate and vigorous intensity for at least 20-30 minutes per day on 3-5 days per week (Thompson, 2010). However, if you have been mostly sedentary and begin a new exercise program, you may need to start below the minimum recommendations. As fitness levels increase, you will want to adjust the F.I.T.T variables in order to continue your progression, but it is important to do this at a relatively gradual pace, especially if you are experiencing any sort of knee pain. The recommendation is to only change a single variable at a time to allow your body to adjust to the increased exercise load. Therefore, to ease or avoid pain associated with running, avoid significant increases in any of the F.I.T.T principle areas in short amounts of time.
- Terrain:
    - With running, it is important to pay attention to the terrain you cover in your routes. In many cases, running up or down hills can exacerbate knee pain due to the increased patellofemoral forces produced under these conditions. If hills are a large portion of your running routine, you may find it beneficial to locate a flatter route until your knee pain is resolved. Also, running on banked or uneven surfaces like the sides of roads can create an imbalance in the forces acting upon the knee joint. It is better to run on the more even portion of the road when possible to avoid the excess joint stress the banking can cause. Another concern with terrain is the actual surface you are running on. Hard surfaces like concrete and asphalt produce greater impact forces than softer surfaces like grass or dirt trails. Reducing the impact forces on your knees during your run by changing to softer paths may be a good way to reduce knee pain, but be aware that these types of paths may have holes or roots that can be tripping hazards. In addition to naturally softer surfaces, the majority of treadmills provide less impact forces on the knee than roads.

Strength Training:

- Hip Abductor Strengthening:
  - Studies have shown that people with knee pain, especially PFPS, have a greater hip adduction angle while running than their healthy counterparts (Noehren, Hamill, & Davis, 2013). When the hip abductor muscles are weak compared to the hip adductor muscles, it can cause a greater degree of hip adduction that normal. This increased adduction can cause the patella to track more laterally in the patellar groove. When the patella is maligned during repetitive motions like running, the abnormal friction can cause damage and inflammation, which leads to pain. Studies have shown that strengthening the hip abductor muscles can result in reduced knee pain. A study by Ferber et al. (2011) compared hip abductor strength between a group of patients with PFPS and a control group without pain. Prior to a hip abductor strengthening intervention, the researchers found that strength was significantly weaker in the PFPS group than the control group. The PFPS group then performed a set of two common exercises to strengthen the hip abductors, which included hip abduction with the leg straight and extension of the leg backward at a 45-degree angle. Both of these exercises were performed using a resistance band, and subjects were instructed to complete 3 sets of 10 repetitions daily for 3 weeks. At the post-test, significant improvements in hip abductor strength were found in the PFPS group. This study also found about a 40% reduction in pain from the pre-test to the post-test, suggesting just 3 weeks of 2 simple exercises per day may be part of an effective treatment for PFPS on other related forms of knee pain..
- Quadriceps Strengthening:
  - Weakness or imbalance in the quadriceps has been consistently associated with knee pain. A study by Khayambashi et al. (2014) examined the effects of hip abductor strengthening versus targeted quadriceps strengthening in subjects with anterior knee pain. The exercises for the hip abductor strengthening were much the same as previously described in this guide, while the exercises for the quadriceps included knee extensions against a resistance band and partial squats against a resistance band with a ball held between the knees. The results found significant reductions in pain and improvements in functional ability and stiffness for both exercise groups. The improvements were more profound in the hip abductor strengthening group, but still significant in the quadriceps strengthening group. This suggests that a combination of hip abductor and quadriceps strengthening may provide a more well rounded and beneficial program than either type of exercise on its own.

- Proximal Stability Strengthening:
    - In addition to focused strengthening of the hip abductor muscles as described previously, a study by Earl and Hoch (2011) looked at the effects of a proximal stability strengthening program on knee pain, specifically PFPS. This program was designed to increase both strength and control of the muscles of the hip abductors and core. The program was performed for 8-weeks and a table with the specific exercises included in the proximal stability program is provided below. The results of the post-rehabilitation tests showed significant increases in hip abduction strength and core strength. The researchers also found significant improvements in pain scores and functional ability in the patients after the completion of the program. Based on these results, adopting the exercises from this proximal stability program may help to reduce your knee pain in a similar way.

Table 1. Proximal stability rehabilitation program utilized by Earl and Hoch (2011) to examine the program's effects on pain, function, and strength in PFPS.

Phase 1 (Weeks 1-2)	Phase 2 (Weeks 3-5)	Phase 3 (Weeks 6-8)
• Abdominal draw-in	• SLS with hip abduction	• "Monster walks"
• Quadruped arm/leg extensions	• Single leg cable column exercise	• SLS with sport-specific upper body movement
• Side-lying clamshells	• SLS quick kicks	• Mini-squat progression
• Supine arm/leg extensions	• Plank exercise	• Hamstring stretch
• Side-lying straight leg raises	• Side plank exercise	• Quadriceps stretch
• Single leg stance (SLS)	• Mini-squat	• Calf stretch
• Hamstring stretch	• Hamstring stretch	• IT band "pretzel" stretch
• Quadriceps stretch	• Quadriceps stretch	
• Calf stretch	• Calf stretch	
	• IT band "pretzel" stretch	
Progression: Dynamic exercises: 3 sets x 10 reps, 3 sets x 15 reps, 3 sets x 20 reps Isometric exercises: 2 sets x 15 reps x 10 second hold Within each phases, progress by adding weight (2.5-5lbs) or increasing level of resistance band.		

Flexibility Training:

- Recommendations by the American College of Sports Medicine are to perform stretching exercises on at least 2-3 days per week (Thompson, 2010). These stretching bouts should last at least 10 minutes, include 4 or more repetitions per stretch, and be held for 15 to 60 seconds. A stretch should be performed with an intensity that produces mild discomfort, but not pain.
- Hamstring Stretch:
  - Sitting for extended periods of time or repetitive bent knee motions can cause tightened hamstrings. This can put strain on the knee joint and cause pain. By performing hamstring stretches daily, you can increase flexibility over time and hopefully ease knee pain. This is especially useful for conditions like pes anserine bursitis, which can be caused by the friction of semitendinosus tendon of the hamstrings on the bursa at its attachment point on the tibia. One example of a hamstring stretch can be performed in a chair with one leg extended and one leg bent. From this starting position, you can hinge forward at the hips and reach down along the extended leg until you feel the stretch at the back of the upper thigh. Other variations on this hamstring stretch exist which include standing and lying versions.
- IT Band Stretch:
  - A tight IT band may cause some of the friction and pain associated with ITBS and other types of knee pain. There are various stretches that can be used to increase the flexibility in a tightened IT band. For one such stretch, you can cross the right leg in front of the left leg and lean into the left hip. This will stretch the left IT band and can be repeated on the other side. A wall can be used for support in order to really sink into the hip lean and get a good stretch. Another IT band stretch is called the pretzel stretch and is also part of the proximal stability protocol previously mentioned. This stretch is performed starting with hands and knees on the ground. One leg is then extended behind while the other leg is bent underneath the body so that the knee faces out and foot crosses the midline. You then lean your upper body onto the side with the bent leg. Performing these types of IT band stretches can help to improve flexibility in the thick connective tissue structure and may help to alleviate some knee pain.
- Calf Stretch:
  - Calf stretches can alternatively be called heel chord stretches, gastrocnemius stretches, and Achilles tendon stretches. The gastrocnemius crosses the knee joint and aids in flexion of the knee, so tightness in the calf can result in some degree of knee pain. There are numerous types of calf stretches that can be performed to improve flexibility in the back of the lower leg. One stretch is to hold onto a wall or chair for support, extend one leg back and bend the other leg in front. By sinking into the bent leg and pressing the back heel into the floor, you stretch and lengthen through the calf muscle. You can also passively stretch this muscle/tendon structure by sitting on the ground with the legs extended. Then, using a resistance band or other assistive device, you can pull your toes towards the body.

Stride Rate:

- Increase 5-10%:
  - Multiple studies have shown that increasing running stride rate by 5-10% has produced significant reductions in patellar joint impact forces (Allen, 2014; Chumanov, Wille, Michalski, & Heiderscheit, 2012; Ferber, Kendall, & Farr, 2011; Lenhart, Thelen, Wille, Chumanov, & Heiderscheit, 2014). Increasing stride rate takes practice and will also cause a shortening in stride length when retaining the same speed. Researchers retrained their subjects by first evaluating their natural stride rate, measuring their strides per minute once a steady state was reached during a treadmill test. Once a baseline was established, a 5-10% increase in stride rate was calculated. For example, if a runner's baseline stride rate was found to be 160 strides per minute, a 5% increase would be 168 strides per minute and a 10% increase would be 176 strides per minute. Once the new stride rates were calculated, a metronome was used to retrain the runners to step in time with the set beat. Eventually, subjects were weaned from using the metronome for timing their steps and the new, faster stride rate was retained. This change in gait mechanics reduced forces on the knee joint and helped to reduce pain in the majority of subjects.

Stride Length:

- Shorten by 5-10%:
  - The principles behind decreasing your stride length are much the same as the ones behind increasing stride rate. This is because at a given speed, if stride length is shortened then stride rate will increase and vice versa. By shortening your stride, patellofemoral joint stress can be reduced, thereby helping to alleviate some knee pain. A study by Willson et al. (2014) assessed changes in patellofemoral joint stress under step length conditions of preferred length, 10% greater than preferred length, and 10% less than preferred length. It was found that compared to the preferred length condition, patellofemoral joint stress was 22.2% less in the shortened stride length condition and 31% more in the lengthened stride length condition. In addition, this study found that though decreased stride length causes an increase in steps per mile, the overall joint stress was still significantly reduced in the shortened stride length condition compared to both the preferred length and the longer than preferred length.

Trunk Posture:

- Forward Lean:

  Another strategy for reducing patellofemoral joint stress may be to adopt a slight forward leaning trunk posture. A study by Hsiang-Ling and Powers (2014) assessed patellofemoral joint forces while running with a preferred trunk posture, a slightly flexed posture, and a slightly extended posture. The subjects were asked to maintain flexed posture or extended posture that stayed within a range in which they felt comfortable running. The difference in flexion angle was 6.8 degrees between the preferred trunk posture and the flexed posture, and 3.3 degrees between the preferred trunk posture and the extended posture. The results showed that a forward flexed trunk posture of just 6.8 degrees found a 6.0% reduction in patellofemoral joint stress compared to a 7.4% increase in peak joint stress under just 3.3 degrees of trunk extension. From this study we can see that adopting even a slight forward lean in your trunk posture while running may reduce the stress and impact forces or your knees which may help to ease knee pain.

Foot Strike Pattern:

- Forefoot Strike versus Rearfoot Strike
  - The majority of runners employ a rearfoot strike technique, but there is a small portion of the running population favor a forefoot strike pattern. The current research on the effects of adopting a forefoot strike versus a rearfoot strike has been conflicting. A forefoot strike (FFS) is defined as initial contact with the anterior one-third of the foot. With a rearfoot strike (RFS), initial contact is made with the heel or posterior one-third of the foot. Studies have found that habitual rearfoot runners have an increased stance time, decreased stride rate, decreased ankle forces, and increased knee forces when compared to habitual forefoot runners (Stearne, Alderson, Green, Donnelly, & Rubenson, 2014). Multiple studies have also shown that many of the biomechanical traits found in habitual runners of each technique can be replicated when switching techniques with little practice (Boyer, Rooney, & Derrick, 2014; Stearne et al., 2014). As for alleviation of knee pain, some researchers suggest that the increased ground reaction forces and increased knee forces associated with RFS may put those using this technique at greater risk for knee injury. However, conclusive evidence for switching to a FFS from a RFS is lacking. In fact, Stearne et al. (2014) found that the slight reductions in forces at the knee when employing a FFS pattern were negligible compared to the significant increase in ankle forces as compared to the RFS technique. The researchers suggest that this may make the forefoot runner more susceptible to ankle injuries while only slightly reducing the effects of joint forces on knee pain. Therefore, based on the current evidence, the author cannot make a clear recommendation for adopting either a forefoot or rearfoot running pattern, but rather presents both sides of the argument and encourages the reader to find what works for them.

Footwear:

- Running Shoe versus Barefoot
    - Much the same as foot strike pattern, there is debate over the best type of running footwear, or lack thereof. Traditional running shoes have padded heels and relatively rigid structures to provide motion control at the ankles. This is thought to reduce impact forces and abnormal running patterns that may lead to lower extremity pain and injury. However, a study by Bonacci et al. (2014) found that stress on the patellofemoral joint was actually increased while running in a shod condition as opposed to a barefoot condition. This was thought to be due to the body's natural change in mechanics to avoid high impact forces in the barefoot condition. For example, this and other studies have found that when habitually shod runners switch to a barefoot condition, stride length is decreased, step rate is increased, and the foot adopted a more midfoot or forefoot strike at initial contact. These mechanical factors may help reduce the patellofemoral joint stress and thus reduce knee pain. Other studies have found that the reductions in peak ground reaction forces in barefoot running are more related to the associated change to a forefoot or midfoot strike than directly related to shod versus unshod conditions. Lieberman et al. (2010) found that when runners retained a rearfoot strike under barefoot conditions, the impact force and loading rate were significantly higher than the rearfoot shod condition or the forefoot barefoot condition. Therefore, when switching to barefoot running, it is important to alter foot strike pattern as well in order to achieve benefits.
- Minimalist Shoes
    - Minimalist shoes like the Vibram Five Fingers shoes have increased in popularity in recent years. This stems from the benefits of barefoot running mentioned above, but more research must be done to conclusively prove that these benefits are mimicked in the minimalist footwear. A study by Sinclair (2014) found that patellofemoral contact forces were significantly reduced while running in minimalist footwear as compared to traditional running shoes. The reduced patellofemoral contact forces in the minimalist shoe condition were statistically similar to the forces measured in the barefoot condition. This study also noted that while forces at the knee were reduced, the forces on the Achilles tendon at the back of the ankle were significantly increased, which may make the ankle more susceptible to injury (Sinclair, 2014). However, another study by McCallion et al. (2014) found that mechanical variables during minimalist running trials like stride length and stride rate were more statistically similar to conventional running shoes than to a barefoot running style. Overall, more research should be conducted on the benefits of minimalist running shoes, but anecdotally, they seem to provide a smooth transition between traditional running shoes and barefoot running.

Ice:

- For the majority of injuries, knee pain included, ice can be used. Ice will slow down metabolic function in the area, prevent further swelling, ease inflammation, and decrease pain. However, it is important to use ice correctly to avoid causing further damage.
- Cold Packs:
  - The most effective types of cold packs are those that can mold around the pained area. A plastic bag filled with ice chip is the best, but freezable gel packs work as well. To increase the conduction of cold into the body part and to avoid direct contact between the ice and the skin, a wet towel can be placed between the cold pack and the area you are icing. It is important to leave the ice in place for no more than 20 minutes as damage to the tissue may occur after that point.
- Ice Massage:
  - Ice massage can be a very effective therapy for knee pain and soreness. The easiest way to perform an ice massage is with a frozen Styrofoam cup of water. When ready for the ice massage, just tear off the top edges of the cup so that about a half inch of ice is exposed and you have the bottom half of the cup left to hold onto. Then proceed to massage the pained area with the ice for 5-10 minutes until it feels numb. Be sure to keep the ice cup moving to avoid damage due to prolonged exposure to direct cold. Try to avoid massaging directly over places where little separates bone from skin, like directly over the kneecap. These areas will get colder faster and are more prone to damage due to the cold because there is less insulation.

NSAIDS:

- Reduce mild inflammation:
  - NSAIDS are anti-inflammatory medications that can be used ease some of the discomfort associated with inflammation caused by overuse injuries. Examples of common NSAIDS are ibuprofen, naproxen sodium, and aspirin. Please note that the author of this guide is not a doctor and usage of NSAIDS without a doctor's approval should only be used to ease relatively mild discomfort. Always follow dosages on the medication bottle and see a doctor if pain continues or gets worse.
- See a Doctor
  - Get doctor's recommendation for anything more serious than mild discomfort and inflammation.

Patellar Bracing:

- Patellar Taping
    - The subject of taping to reduce pain and risk of injury is extremely broad. There are a wide variety of techniques that may be beneficial for a number of the causes of knee pain discussed in this guide. However, your options with taping should be discussed with a professional, such as a physical therapist or an athletic trainer, before trying any of the methods on your own. By speaking with a medical professional, they will be able to recommend a specific taping style and provide instruction for performing the taping safely without causing more damage.
- Infrapatellar Straps:
    - Infrapatellar straps are commonly recommended for a number of types of knee pain including patellar tendinitis and PFPS. A study by Lavagnino et al. (2011) looked into the effects of infrapatellar straps on strain at the patellar tendon in healthy subjects. The researchers found that patellar tendon strain was reduced when using two different brands of infrapatellar straps when compared to the same subjects tested without the straps. This suggests that individuals suffering from patellar tendinitis can use infrapatellar straps to reduce strain to the tendon and thus reduce pain.
- Knee Sleeve
    - Knee sleeves, commonly made of neoprene or cloth, have been shown to provide relief from knee pain in some cases. The sleeve provides compression and stabilization of the patella in order to increase joint contact area (Wilson, Mazahery, Koh, & Li-Qun, 2010). In the knee, while the overall stress on the joint may be the same, increased joint contact area allows this stress to be spread out rather than localized to a single point. Also, some sleeves have buttress padding that, along with the compression, helps to keep the patella in a more proper alignment. A study by Lun et al. (2005) found that the use of knee sleeves significantly reduced pain and improved functional ability in patients suffering from PFPS. Knee sleeves are also relatively inexpensive and can be purchased at your local sporting goods store.

Orthotics:

- Some knee pain can come from abnormal movement at the ankle joint. One of the common abnormal movements that lead to knee pain is over pronation of the foot during stance phase. Over pronation is an outward rolling of the ankle as the foot makes initial contact during the running stride. This excessive pronation is thought to cause instability at the foot, which in turn causes instability and risk of injury at the knee through the kinetic chain. If you suspect your knee pain stems from excessive pronation, it may be beneficial to make an appointment with an orthotics specialist. A study by Shih, When, and Chen (2011) found benefits of a relatively small, rearfoot, medially wedged insole. This option was less expensive than a traditional orthotic and provided significant reduction in anterior knee pain while running between the pre-tests and the post-tests. In fact, after two weeks of wearing the wedged insole, the 58% of the treatment group were able to run the 60-minute treadmill test pain free as compared to 8% in the control group. Another study found that increased pronation velocity was a key factor in the development of patellar tendinitis (Grau et al., 2008). An orthotics specialist would be able to fit you with a pronation velocity control orthotics to reduce this problem.

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