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# Anatomy, Bony Pelvis and Lower Limb, Leg Bones

**Authors**

Austin J. Cantrell[1]; Matthew Varacallo[2].

**Affiliations**

[1] University of Oklahoma College of Med.
[2] Department of Orthopaedic Surgery, University of Kentucky School of Medicine

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## Introduction

The leg is the region of the lower limb between the knee and the foot. It comprises two bones: the tibia and the fibula. The role of these two bones is to provide stability and support to the rest of the body, and through articulations with the femur and foot/ankle and the muscles attached to these bones, provide mobility and the ability to ambulate in an upright position. The tibia articulates with the femur at the knee joint. The knee joint consists of three compartments [1][2]

- medial tibiofemoral compartment
- lateral tibiofemoral compartment
- patellofemoral compartment

At the ankle, the tibia and fibula create the articular surface for the talus. The ankle mortise is a specialized articulation providing support and optimizing motion and function through the ankle joint. A normal ankle joint ultimately optimizes and allows for physiologic mobility of the foot and its associated joints and articulations. The bones and fascia also divide the lower leg into four compartments [3][4]

- anterior compartment
- lateral compartment
- posterior compartment, superficial
- posterior compartment, deep

## Structure and Function

The tibia is the second largest bone in the body and provides support for a significant portion of the weight-bearing forces transmitted from the rest of the body. Proximally in cross-section, the tibia assumes a pyramidal shape/surface that articulates with the femur at the knee joint. The proximal tibia consists of medial and lateral tibial plateau surfaces, each with an associated meniscus. In the center of the two plateaus is an intercondylar spine which contains a portion of the attachment footprint for the anterior cruciate ligament (ACL). The posterior portion contains a corresponding portion for the attachment footprint of the posterior cruciate ligament (PCL).[2] These ligaments attach the femur to the tibia.

In addition to the ACL and PCL, knee joint stability in the coronal plane is a function of the medial collateral ligament (MCL) and the lateral collateral ligament (LCL). The MCL spans from the medial aspect of the femur to the proximal tibia distal to the joint line. The LCL attaches to the lateral aspect of the femur and courses to the anterolateral fibula head.[5] The patellar tendon also attaches to the proximal tibia.[6] This tendon inserts on the tibial tubercle at the midline on the tibia directly distal to the knee joint. The posterior aspect of the knee provides, in general, stability for the knee in extension. Posterior support of the knee joint is critical as the popliteal region includes the neurovascular bundle which passes through this area to provide significant neurovascular contributions to the lower leg and foot.[7][8]

The fibula is much smaller and provides much less weight-bearing support compared to its tibial counterpart. The fibula connects to the tibia via an interosseous membrane that connects the two bones distally at the ankle joint. Proximally, the proximal tibiofibular joint serves as the proximal anchoring stabilizing connection between the two bones in the lower leg.

The fibula forms the lateral border of the ankle joint while the tibia forms the medial border. Relative to the ankle joint, these osseous segments are referred to as the lateral and medial malleoli, respectively.[9] The osseous integrity of the malleoli and the ankle syndesmosis (including the interosseous membrane and syndesmotic ligaments) serve to provide a seamless and confluent ankle mortise that optimizes the delicate balance of tibiotalar mobility and stability. The medial malleolus provides attachment points for the large deltoid ligament, the posterior tibiotalar ligament, the tibiocalcaneal ligament, and the tibionavicular ligament. The lateral malleolus provides an attachment for the anterior talofibular ligament, the calcaneofibular ligament, and the posterior talofibular ligament.

## Embryology

The lower limbs form in the fourth week of prenatal development. They develop in a cranial to caudal direction. Ossification centers form in the tibia around the sixth week, and during the seventh or eighth week in the fibula. Each bone forms via endochondral ossification. Fusion of the ossification centers starts around the sixteenth year of life with the proximal ossification center fusing before the distal ossification centers. Fusion of the ossification centers completes normal bone growth.

## Blood Supply and Lymphatics

The arterial supply to the tibia is multifaceted. Branches of the anterior tibial artery supply the proximal metaphysis and epiphysis from the periphery via periosteal branches. The nutrient artery supplies the diaphysis. This artery penetrates the tibia posteriorly, distal to the soleal line near the center of the tibia and sends branches towards the proximal and distal ends of the diaphysis [3]. The penetrating branches of the posterior tibial artery supply the distal metaphysis and epiphysis from the periphery.

The arterial supply of the proximal epiphysis and metaphysis of the fibula is through branches of the anterior tibial artery and more distally by the fibular artery. This blood supply is noteworthy as graft reconstruction surgery of the mandible often uses the proximal fibula.

Venous drainage of the tibia is via the anterior and posterior tibial veins, and fibula drainage is via the fibular vein. These veins drain into the popliteal vein.

The lymphatic drainage of the tibia and fibula is to the superficial and deep inguinal lymph nodes.

## Nerves

Branches from the tibial nerve that supply the knee joint provide innervation to the proximal tibia. Distally, branches from nerves supplying the overlying muscle innervate the tibia below. These are branches of the deep femoral nerve and the tibial nerve.

## Muscles

Muscles demonstrating origin/insertion footprints on the tibia include [10][11][12][13][14][15]

- Tensor fasciae latae inserts on the lateral (Gerdy) tubercle of the tibia.
- Quadriceps femoris inserts anteriorly on the tibial tuberosity.
- Sartorius, gracilis, and semitendinosus insert anteromedially on the pes anserinus.
- Horizontal head of semimembranosus muscle inserts on the medial condyle.
- Popliteus inserts on the soleal line of the posterior tibia.
- Tibialis anterior originates at the upper two-thirds of the lateral tibia.
- Extensor digitorum longus originates at the lateral condyle of the tibia.
- Soleus and flexor digitorum longus originate at the posterior aspect of the tibia on the soleal line.

Muscles associated with the fibula:

- The biceps femoris tendon inserts on the fibular head.
- The fibularis longus and fibularis brevis tendons insert on the lateral fibula.
- The extensor digitorum longus and extensor hallucis longus tendons insert on the medial fibula.
- The fibularis tertius (FT) is a small muscle in the anterior compartment of the leg that inserts on the anterior surface of the distal fibula.[16]

## Surgical Considerations

**Tibial Fractures**

Fractures involving the tibia are relatively common injuries. Tibial plateau fractures are proximal tibial fractures with extension into the articular surface. In general, these fractures have significant associated morbidity and long-term implications that can significantly impact patient function and outcomes. For example, tibial plateau fractures correlate with [17]

- Meniscal tears:
    - Lateral meniscal tears
        - More commonly associated lateral tibial fractures (e.g., Schatzker II pattern)
        - Associated with greater than 10mm of articular depression
    - medial meniscal tears
        - More commonly associated with medial tibial plateau fractures (e.g., Schatzker IV pattern)
    - ACL injuries
    - compartment syndrome

- vascular injury

Operative fixation is often necessary for the setting of increasing displacement and associated injury. [18] Post-traumatic deformity and/or end-stage arthritis is not tolerated without subsequent orthopedic intervention in these patients.  End-stage arthritic changes and deformity require the spectrum of knee reconstructive options, such as total knee arthroplasty (TKA).[1]  In the appropriate patient, TKA is a consistently successful and reproducible procedure that can restore mobility and function these debilitated patients.[19][20]

Tibial shaft fractures can occur and are often open due to the proximity to the skin of the tibia. Operative treatment may be required, consisting of open reduction internal fixation (ORIF) with plate/screws, external fixation, or intramedullary nail fixation.[21]

**Ankle Fractures**

Ankle fractures in general constitute a wide range of injury patterns, bony/ligamentous involvement, and potential instability.[9]  Mechanisms of injury often include some combination of rotational force(s) combined with inversion or eversion pathologic positioning at the time of injury and fracture.  Although the comprehensive treatment/workup is beyond the scope of this review, ankle fractures are diagnosed utilizing a combination of patient-reported history, the presence of deformity/pain on the exam, and radiographic imaging.  A 2017 systematic review with meta-analysis investigating the diagnostic accuracy of the Ottawa ankle rules demonstrated that the sensitivity of the scoring system was more sensitive in adults compared to children, and the influence of subspecialty profession by the healthcare provider had a negligible influence on the overall diagnostic accuracy.  The authors concluded that, across the 66 included studies in the review, the ankle rules were consistently found to have a high sensitivity and low negative likelihood ratio, indicating that a negative test result is highly informative in excluding a fracture of the ankle, thus obviating the need for further radiographic imaging.[22]

**Fibular Grafting**

The advantage of the fibula being a large, relatively non-weight-bearing bone is clear in its use as a bone graft during mandibular reconstruction. This is the “gold standard” with several variations in the surgery being developed. The fibula has a large amount of dense cortical bone that is easily accessible and a highly vascularized intrinsic blood supply that will decrease union time. This vascularity has been shown to be superior to non-vascular bone grafts in both functionality and aesthetics.[23]

Fibular strut grafts are also often utilized in various procedures to augment surgical fixation in the setting of comminuted fragility fractures (i.e., those occurring secondary to osteoporosis or low bone mineral density.)[24][25] For example, fibular strut grafting is commonly used in osteopenic patients with comminuted proximal humerus fractures undergoing ORIF with plate/screws.[26][24]

## Clinical Significance

Medial tibial stress syndrome, more colloquially known as shin splints, is most commonly seen in runners and dancers who overload their lower extremity with recurrent pressure and typically presents with pain overlying the tibia that gets worse with repeated use. Medial tibial stress syndrome is diagnosed with the physical exam, by repeated palpation of the tibia causing pain. Treatment involves rest and ice until pain dissipates.[21]

Apophysitis of the tibial tubercle, or Osgood-Schlatter disease, is another pain syndrome of the tibia. The pain is located directly below the knee with that, like shin splints, gets worse with activity and improves with rest; this is the point where the patellar tendon inserts on the tibia and can become stressed with repeated use of the knee. A palpable bony prominence can be present, and palpation to this point can be extremely painful. Rest and ice are the mainstays of treatment. Since this syndrome is most common in ten to fifteen-year-olds, the symptoms usually resolve as the epiphyseal plates close.[21][6]

Compartment Syndrome is a significant complication of tibial fractures and other traumas to the leg. Following the trauma, blood and other fluids fill the compartments created by the thick fascia and bones. This increased fluid within the compartments causes an increase in pressure that can compress the venous return which can lead to tissue ischemia and cellular death.[27] Within six to eight hours of compression, irreversible damage to the muscles and nerves within the compartments. Monitoring the intramuscular pressure is the current basis of diagnosis although other methods are under investigation. The mainstay of treatment is rapid fasciotomy to decrease pressure and restore venous return.[28]

## Questions

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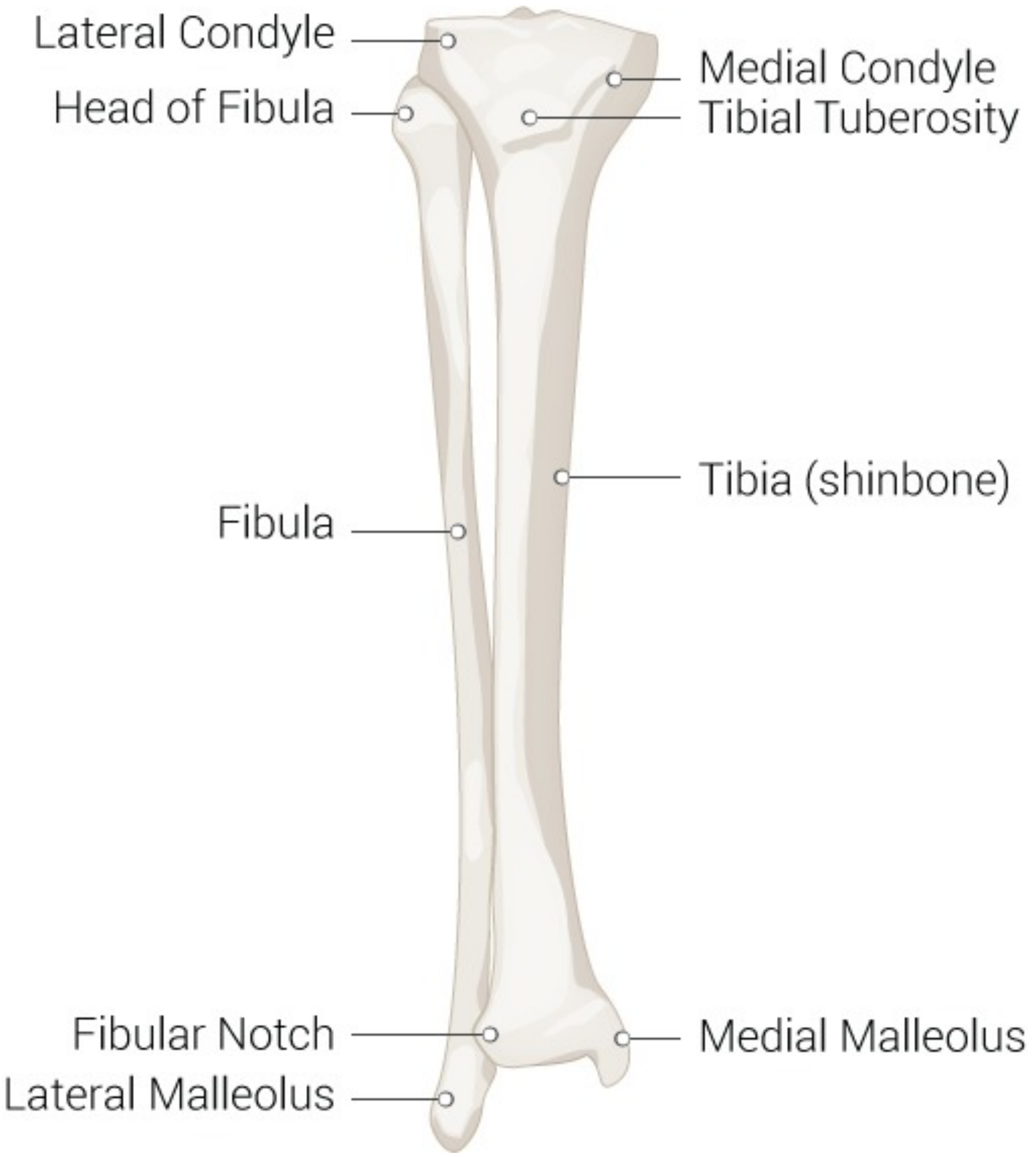
## Figures




Tibia, Fibula, Fibular Notch, Lateral Malleolus, Medial Malleolus, Lateral Condyle, Medial Condyle, Tibial Tuberosity, Head of Fibula. Contributed Illustration by Beckie Palmer



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