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Anatomy of the Ankle and Ankle Injuries in Athletes

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University Honors Program, Northern Illinois University

BIOS 495: Directed Research in Biology

Mrs. Kara Coffman-Rea

December 10, 2023
Abstract

The purpose of this project was to learn about the anatomy of the ankle joint, explore common ankle injuries in athletes, and research how they are treated overall and in a physical therapy setting. To do so, a dissection of the ankle joint was completed with Mrs. Kara Coffman-Rea in the cadaver lab as well as an exploration of plastinated models. Additionally, a literature review of current research on the ankle was completed. Though many structures of the ankle joint were identified through dissection, the focus of the literature review is on the structures of the lateral ankle and the Achilles (calcaneal) tendon. For the purpose of the project, photos were taken of the structures of the ankle joint throughout the dissection, and these pictures were labeled appropriately. This project is relevant to my studies because I am aiming to attend a Doctor of Physical Therapy program in the fall. It is pertinent to my future career goal to have experience working in a cadaver lab, learn more about the body, and understand how certain parts of the body are treated in a physical therapy setting.
Literature Review

The literature review for this project was completed by using the Northern Illinois University Library Databases to find the most common ankle injuries in the athletic population. Multiple databases were used, and the findings of the research are synthesized in this literature review.
**Anatomy of the Lateral Ankle**

The anatomy of the lateral ankle consists of the anterior talofibular ligament, calcaneofibular ligament, the posterior tibiofibular ligament, and the posterior talofibular ligament. Each structure has its own purpose, and they all work together to allow the ankle joint to function properly. Information about each ligament is provided in Table 1. Additionally, the common actions of the ankle are plantar flexion, dorsiflexion, inversion, and eversion. Information about these actions is provided in Table 2.

<table>
<thead>
<tr>
<th>Ligament</th>
<th>Proximal attachment</th>
<th>Distal attachment</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior talofibular</td>
<td>Lateral malleolus</td>
<td>Neck of the talus</td>
<td>Supports lateral ankle joint</td>
</tr>
<tr>
<td>Calcaneofibular</td>
<td>Tip of the lateral malleolus</td>
<td>Lateral part of the calcaneus</td>
<td>Supports lateral ankle joint</td>
</tr>
<tr>
<td>Posterior tibiofibular</td>
<td>Posterior portion of the fibular head</td>
<td>Lateral tibial condyle (posterior part of the tibia)</td>
<td>Supports lateral ankle joint</td>
</tr>
<tr>
<td>Posterior talofibular</td>
<td>Malleolar fossa</td>
<td>Lateral tubercle of the talus</td>
<td>Supports lateral ankle joint</td>
</tr>
</tbody>
</table>

*Table 1*. Descriptions of lateral ligaments of the ankle (Moore et al., 2014).

<table>
<thead>
<tr>
<th>Action</th>
<th>Description of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar flexion</td>
<td>The toes are pointed down towards the ground</td>
</tr>
<tr>
<td>Dorsiflexion</td>
<td>The toes are pointed up, the dorsum of the foot is brought closer to the leg</td>
</tr>
<tr>
<td>Inversion</td>
<td>The medial side and sole of the foot turn toward the midline causing the outward rolling of the ankle</td>
</tr>
</tbody>
</table>
Eversion

The lateral edge of the foot turns laterally away from the midline causing inward rolling of the ankle

| Table 2. Descriptions of actions of the ankle (Moore et al., 2014). |

**Ankle Sprains**

The ankle joint is frequently injured, and lateral ankle sprains are a type of injury that occur most often (Moore et al., 2014). According to Wang et al. (2023), lateral ankle sprains occur when the foot is inverted or when plantar flexion and inversion occurs. The lateral ligament is not as strong as the medial ligament, and therefore it is more susceptible to injury (Moore et al., 2014). Specifically, the anterior talofibular ligament is more susceptible to being torn (Moore et al., 2014). Other anatomical structures may become injured, depending on the severity of the injury, like the calcaneofibular ligament, which may be torn, and the lateral malleolus could potentially become fractured (Moore et al., 2014).

There are different levels of ankle sprains that can be used to identify the severity of the injury to the anatomical structures, and what approaches to take for rehabilitation. The three levels of ankle sprain are Grade 1, Grade 2, and Grade 3. A Grade 1 sprain consists of the ligament being lengthened and stretched out, but there are no signs of the joint lacking stability, there is little swelling, and pain levels are low. An athlete may be on the sidelines for around one week with this grade of a sprain. If an athlete has a Grade 2 sprain, some of the ligaments have torn, there is evidence of some joint instability, levels of pain are much higher than a Grade 1 sprain, and the ankle may need to be immobilized for a few days. If an athlete has a Grade 3 sprain, a ligament has ruptured, there is significant joint instability, and pain and swelling levels are very high, which causes the athlete to be non-weight bearing for a few weeks (Chinn & Hertel, 2010).
**Prevalence in Athletes**

Ankle injuries and ankle sprains are among the most common injuries for athletes. A comprehensive review by Fong et al. (2007) examined 70 sports and assessed the most common part of the body that is injured in each sport. Out of these 70 sports, the most commonly injured body part was the ankle for 24 of them, including indoor volleyball, mountaineering, track and field, field hockey, and gymnastics. Additionally, they reported prevalence of specific ankle injuries among 43 different sports, and ankle sprains were the most prevalent injury for 33 of these sports (Fong et al., 2007). Brown et al. (2023) reported that lateral ankle sprains are common in collegiate sports and can impact Division I athletes participating in many different sports. A significant amount of these injuries caused these athletes to have to take time away from their sport (Brown et al., 2023). It is evident that ankle injuries are prevalent in the athletic population, and impact athletes who participate in many different sports. Therefore, it is necessary for clinicians, including physical therapists, to know how to effectively address these injuries.

**Rehabilitation and Prevention Techniques**

There are many different rehabilitation techniques and interventions that can benefit athletes who have an ankle sprain. First, it is important to note that the treatment should reflect the phase of recovery the athlete is in (Mattacola & Dwyer, 2002). In the early stages, rehabilitation should focus on regaining range of motion, as well as gaining back strength by focusing on isometric exercises and isotonic exercises (Mattacola & Dwyer, 2002; Chinn & Hertel, 2010). For patients who are not weight bearing, clinicians can focus on open-chain exercises to regain range of motion (Chinn & Hertel, 2010). Clinicians, including physical therapists, should focus on range of motion both actively and passively and specifically target
dorsiflexion and plantar flexion (Chinn & Hertel, 2010). This can be accomplished through mobilization with movement strategies, which physical therapists can perform (Vicenzino et al., 2006). These movements can help to make improvements in posterior talar glide, which can be impacted by lateral ankle sprains, and can also help improve dorsiflexion (Vicenzino et al., 2006). Different modalities can also be used, including a wobble board, hydrotherapy and the stationary bike, to work on range of motion (Chinn & Hertel, 2010).

Once this stage has been passed, the next stage of rehabilitation can begin, which includes a focus on working on proprioception and gaining back neuromuscular control (Chinn & Hertel, 2010; Mattacola & Dwyer, 2002). Range of motion should still be a focus of physical therapy and rehabilitation (Chinn & Hertel, 2010). Balance will become an increased focus during this stage, with a transition from balancing on both feet to balancing on one foot, and surfaces that lack stability will be used as the athlete progresses (Chinn & Hertel, 2010). As time continues, more challenges can be added, including having the athlete close their eyes (Chinn & Hertel, 2010). Additionally, more advancements can be added including throwing and catching objects that are weighted, adding arm movements, and squatting, which can help with ankle stability (McKeon et al., 2008). The physical therapist can also slightly tap the athlete while balancing to help them retrain and learn how to get back on balance and work on ankle stability (Mattacola & Dwyer, 2002).

As swelling and pain levels decrease, strength can be a more prevalent focus of rehabilitation. The focus will start with plantar flexion and dorsiflexion, and then move to inversion and eversion, and strength in these different directions can be gained with the use of resistance band exercises (Chinn & Hertel, 2010).
It is crucial that athletes are being educated during the rehabilitation process on proper ways to move after an ankle injury (Chinn & Hertel, 2010). It is then essential to focus on exercises that are specific to the sport the athlete participates in (Chinn & Hertel, 2010; Mattacola & Dwyer, 2002). The clinician should focus on integrating movements that are specific to that athlete, including movement patterns and equipment worn during the sport, like the proper shoes (Chinn & Hertel, 2010).

Not only is it important for athletes to be educated on rehabilitation techniques, but it is also important for preventative techniques to be used to prevent lateral ankle sprains from occurring or re-occurring (Wang et al., 2023). Proprioceptive training was found to be an important intervention to prevent future ankle sprains (Wang et al, 2023). There were varied results found for the effectiveness of ankle bracing for preventing lateral ankle sprains, and it may depend on the case (Wang et al., 2023).

**Anatomy of the Achilles Tendon**

The Achilles, or calcaneal tendon, is an anatomical structure that is part of the ankle. It provides stability for the ankle, and also allows plantar flexion of the foot. Information about the Achilles tendon is provided in Table 3.

<table>
<thead>
<tr>
<th>Tendon</th>
<th>Proximal attachment</th>
<th>Distal attachment</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achilles (Calcaneal Tendon)</td>
<td>Soleus, Gastrocnemius, Plantaris</td>
<td>Calcaneus</td>
<td>Stabilization of the ankle and plantar flexion of the foot</td>
</tr>
</tbody>
</table>

*Table 3. Description of Achilles tendon (Moore et al., 2014).*

**Achilles Tendinopathy and Ruptured Achilles Tendon**

Achilles tendinopathy is an injury that occurs due to overuse (Andres et al., 2008). It is a general term that encompasses pain that is associated with tendons that are being overused
(Andres et al., 2008). A rupture of the Achilles tendon often occurs in individuals with calcaneal tendinitis (Moore et al., 2014). It usually occurs due to a plantar flexion motion with a straight knee, quickly followed by intense, dorsi flexion of the foot (Moore et al., 2014). When this occurs, a snapping or popping sound is associated with this injury (Moore et al., 2014). If the tendon fully ruptures, a gap may be present (Moore et al., 2014). This is a very significant and drastic injury of the leg (Moore et al., 2014).

**Prevalence in Athletes**

Achilles tendinopathy is fairly common in the athletic population. Specifically, for elite athletes, this tendinopathy is common, but the extent to which athletes experience this condition depends on the sport they play, with athletes who go a fair amount of distance having a higher likelihood of experiencing Achilles tendinopathy (Janssen et al., 2018). These injuries occur in both the general population and in athletes (Li & Hua, 2016). Overall, they are more common in individuals whose activities include running and jumping (Li & Hua, 2016).

An Achilles tendon rupture is common in many sports. It is most common in the sport of basketball (Berkay et al., 2023). Another sport where it is common is gymnastics, specifically collegiate-level gymnasts, and the injury usually occurs on the floor exercise (Kobayashi et al., 2023). Additionally, according to a study from the American Orthopedic Society for Sports Medicine, most Achilles tendon ruptures occurred during an injury that did not involve contact with others, and the athlete was in knee and hip extension, as well as in a position where the ankle was dorsiflexed (Gronwald et al., 2023). Specifically, the injury occurred in athletes when they were stepping behind themselves, landing, running, jumping, or starting a movement, and all movement occurred when their leg was planted on the ground (Gronwald et al., 2023).
Rehabilitation Techniques

Different rehabilitation techniques can be used to treat Achilles tendinopathy and Achilles ruptures. For Achilles tendinopathy, there is support for using high-load, slow velocity exercises involving resistance for the athletic population (Taylor et al., 2023). Additionally, non-steroidal anti-inflammatory drugs (NSAIDs) can be used alongside physical therapy (Andres et al., 2008). Eccentric training (which is focused on movements that lengthen the muscle) is a good, evidence-based approach for rehabilitating Achilles tendinopathy (Andres et al., 2008; Sivrika et al., 2023). Though there may not be one specific way to treat Achilles tendinopathy, it is important that practice and athletic activities are adjusted based on what the athlete can manage, and exercises should be curated to that patient specifically (Li & Hua, 2016).

For Achilles tendon tears and ruptures, one important type of rehabilitation is functional rehabilitation, which is focused on returning the athlete to full participation of their sport (Park et al., 2020). Functional rehabilitation is used for Achilles tears that are treated with surgery and without surgery, with the first six months after the injury being a critical time for rehabilitation. Consistent rehabilitation is important during this time for factors like calf strength. Additionally, weight-bearing should be done in the early stages of recovery (Park et al., 2020).

Moreover, a literature review by Zellers et al. (2019) focused on defining functional rehabilitation, as uniform definition lacks consensus in the literature, despite many studies affirming its effectiveness. They found that many different exercises and techniques were used for functional rehabilitation. These can include weight bearing, range of motion, isometrics, exercises focusing on the cardiovascular system, core exercises, and balance exercises. Other exercises included the use of stretching, electrical stimulation, and joint mobilization as well the use of a pool or water for rehabilitation (Zeller et al., 2019). The major commonalities among the
defining features of functional rehabilitation are: (1) that it usually begins around two weeks after the injury occurs or surgery has been done; (2) the focus is on range of motion; and (3) strength-focused exercises are important (Zellers et al., 2019). Physical therapists can implement these exercises to help a patient that is recovering from an Achilles rupture.

The amount of time that rehabilitation takes for a ruptured Achilles may vary. A review done by Gould et al. (2021) found that most rehabilitation techniques start with a focus on improving the range of motion of the ankle joint. This will be followed by different kinds of exercises, including isometric exercises and proprioception exercises. Finally, exercises that focus on strength will be used, including heel raises and squatting on one leg. Additionally, they found that there were multiple studies that used biking and swimming as ways to implement exercise into rehabilitation. Once the patient has gone through all of these phases and exercises, running will be implemented, as well as activities that are designed for the athlete’s particular sport in order to help them prepare to participate in their sport again. The focus of rehabilitation now is less on immobilizing the ankle for a long period of time and more on weight-bearing earlier, so rehabilitation is a crucial part of the recovery process for individuals who have ruptured their Achilles tendon (Gould et al., 2021).
Ankle Dissection

The dissection for this project was done on the ankle joint of a female cadaver in the anatomy lab. The dissection started by removing the lower leg and ankle from the rest of the body. Then, the majority of the musculature was removed from the ankle to reveal the osteological structures, tendons, and ligaments. Portions of the gastrocnemius, soleus, and plantaris muscles were left as they contribute to the Achilles tendon. Subsequent to the removal of the unwanted musculature, the connective tissue was removed carefully to expose the structures of the ankle that help stabilize the joint and contribute to its function. This was done using scissors and a scalpel. Once the connective tissue was removed, the proper structures were revealed and identified. Further cleanup was completed as needed around targeted structures. Throughout the dissection, all safety precautions were implemented. Proper attire and protective equipment, including gloves and safety glasses, were worn at all times. Additionally, the cadaver was respected and handled with care throughout the whole process.
Ethics Statement

The cadaver used in this study was obtained by Northern Illinois University’s Human Anatomical Sciences program. Prior to death, if a person has decided to donate their body to biomedical research, or for educational purposes, they must complete a donor enrollment form that includes: a statement of sound mind, their personal information, and details concerning the transportation of their body, and duration that it will be used for research/educational purposes. The next of kin, executor of the estate, or other responsible party can also complete the paperwork necessary to make the donation. The donor can cancel the donation at any time prior to death.
Osteology of the Ankle

Tibia, Fibula, and Talus
Anterior Tibiofibular Ligament

Proximal Attachment: Anterior part of the lateral malleolus

Distal Attachment: Tibia
Anterior Talofibular Ligament

Proximal Attachment: Lateral malleolus

Distal Attachment: Neck of the talus
Image of Anterior Tibiofibular Ligament and Anterior Talofibular Ligament

These two ligaments are shown in relation to each other in this picture
Achilles (Calcaneal) Tendon

Proximal Attachment: Soleus, gastrocnemius, plantaris

Distal Attachment: Calcaneus
Calcaneofibular Ligament

Proximal Attachment: Tip of the lateral malleolus

Distal Attachment: Lateral part of the calcaneus
Posterior View of the Ankle

**Posterior Tibiofibular Ligament**

**Proximal Attachment:** Posterior portion of the fibular head

**Distal Attachment:** Lateral tibial condyle (posterior part of the tibia)

**Posterior Talofibular Ligament**

**Proximal Attachment:** Malleolar fossa

**Distal Attachment:** Lateral tubercle of the talus
Medial (Deltoid) Ligament
Plastination and Plastinate Models

Plastinate models were used as a part of this project to further study the ankle and be able to identify the anatomical structures of the ankle. Because they are very clear models, they helped to provide clarity on where certain anatomical structures are on the ankle, which helped to build a deeper understanding of the ankle.

The process of plastination is a way to preserve anatomical parts of the human body, and it involves six steps. The first step is fixation, where preserving chemicals, including formaldehyde, are pushed into the arteries. This is done to kill all bacteria and takes around four hours. The next step involves dissecting the cadaver. All of the skin, unwanted soft tissue, and fat are taken off, and this takes hundreds of hours. The third step is where the plastination starts, and the cadaveric specimen is soaked in acetone to remove excess fat and water. The acetone is now in the cells instead of water. The fourth step is called forced impregnation, where the cadaveric specimen is put into a liquid polymer bath, and the polymer, like rubber or resin, replaces the acetone in the cells. This takes anywhere from two to five weeks to complete. Step five of the plastination process involves moving the specimen into the desired position. Tools like wires and clips are used to place each anatomical structure in the correct position, and this process can take a few months in some cases. Finally, step six occurs when the structure is hardened and cured in order to help the plastinate model last for a long time. This hardening process may involve different techniques, like using gas or heat to harden the polymer that was used. The entire process, from step one to step six, takes about one whole year to accomplish (Gubener Plastinate GmbH, 2022).
Labeled Plastinate Models

Medial View
Lateral View
Acknowledgements

I sincerely thank those who donated their bodies to science so that anatomical research could be performed. Results from such research can potentially improve patient care and increase overall knowledge. Therefore, these donors and their families deserve the highest gratitude.

I would also like to sincerely thank Mrs. Kara Coffman for her expertise and guidance throughout this whole project and throughout the dissection experience, which helped me complete a meaningful and successful Honors Capstone Project.
References


