Joint Mobility and Stability Strategies for the Ankle

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ABSTRACT

This monograph details the anatomy and neurophysiology of the multi-segmented ankle-foot complex, injury pathomechanics, and the clinical sequela that ensue following lateral ankle sprain and chronic ankle instability. Impairments in the human movement system, which include deficits in joint mobility and stability, sensorimotor function, postural control, walking, running, and jump-landing are discussed. Changes in pain and measures of health-related quality of life to include physical health, mental health, and function following lateral ankle sprain and chronic ankle instability are also detailed. Suggested clinical evaluation techniques in the assessment and treatment of impairment, activity limitation, and participation restriction following ankle sprain are provided. Three case studies are presented that details the mechanism and sequela regarding lateral ankle sprain and chronic ankle sprain. In the first case, we discuss the physical function of a young man who experienced a first-time ankle sprain during sport. In the second case, we discuss a young man who experienced a first-time ankle sprain 14 months prior who recovered without any residual perceived or episodic instability in the ankle. In the final case, we present a young woman who sprained her ankle for the first time 3 years prior and with regularly recurring perceived and episodic giving-way of the ankle. In the three cases, we detail pain, health-related quality of life, and impairments of the human movement system to include joint mobility and stability, neuromotor function, and dynamic balance in the ankle-foot complex.

Key Words: ankle injuries, musculoskeletal system, rehabilitation, physical examination, therapeutics

LEARNING OBJECTIVES

Upon completion of this monograph, the course participant will be able to:

1. Describe the burden, etiology, assessment, and conservative management of the foot and ankle following lateral ankle instability.
2. Integrate anatomical, biomechanical, and neuromuscular concepts relating to the etiology, examination, and intervention of the ankle-foot complex in individuals with lateral ankle instability.
3. Formulate an evaluation and rehabilitation plan for individuals with lateral ankle instability.
4. Apply evidence-based assessment and intervention methods to the ankle-foot complex.

INTRODUCTION

Lateral ankle sprains are a common injury incurred by athletes,[1,2] military service members,[2–4] and the general public alike.[2,5] They result from high-velocity inversion and internal rotation motions and large moments of the foot and ankle that result in injury.[6,7] A subset of individuals with lateral ankle sprain may also incur a plantar flexion moment that contributes to injury.[8] These deleterious forces damage the neural, connective, and contractile tissues of the multiple segments of the ankle-foot complex that culminate in joint mobility and stability impairment.

While the majority of individuals recover from lateral ankle sprains without persistent functional limitation ("copers"), 40% will progress to develop chronic ankle instability.[9] Chronic ankle instability is a clinical condition characterized by perceived or episodic giving-way of the ankle and disability that persists greater than one year following the index injury.[10] Chronic ankle instability is a heterogeneous condition that has varying degrees of neurophysiologic and mechanical impairment,[11] which adds complexity to the clinical management of these patients. Individuals with chronic ankle instability frequently experience life-long limitation in functional activity and participation restriction.[12–15]

Individuals with a history of lateral ankle sprains and chronic ankle instability have static[16,17] and dynamic[17] balance impairment and altered walking,[18] running,[18] and jump-landing[19,20] mechanics. Afferent and efferent neurophysiologic deficits are a substantial contributor to balance and biomechanical impairment. Sensory impairments such as altered cutaneous sensation in the ankle[21] and foot,[22] proprioception,[17,23] peripheral nerve conduction,[24–27] and higher-order sensory reorganization[28,29] are common following lateral ankle sprain and contribute to altered motor planning and execution. In addition to sensory deficit, motor impairments that includes spinal[30,31] and cortical[32,33] inhibition, altered motor timing, and diminished strength[34,35] contributes to impaired joint stability and movement strategies. Mechanical disruption of the ankle-foot complex that results in joint stiffness, laxity, or positional faults following lateral ankle sprain are also contributory to altered movement during function.

It is important that clinicians be able to assess and treat joint mobility and stability impairment in the multiple segments of the ankle-foot complex following lateral ankle sprain or chronic ankle instability. It is equally important that clinicians consider factors that may influence functional outcomes when caring for these individuals. Therefore, the purpose of this monograph is to explore the anatomical, biomechanical, neurophysiological, and psychological factors related to lateral ankle sprain and chronic ankle instability. Evidence-based rehabilitation management, including select assessment methods and interventions to improve joint mobility and stability in the ankle-foot complex, will be discussed.

THE ANKLE-FOOT COMPLEX

The ankle-foot complex consists of 7 distinct segments: the shank, rearfoot, lateral and medial midfoot, lateral and medial forefoot, and the hallux. Segmental architecture allows the foot to rapidly adapt from a condition that is conducive for force attenuation, accommodation to the ground, and then to a condition optimal for force transmission and propulsion. The ability of the ankle-foot complex to alter morphology (shape) and stiffness are important for force attenuation during load acceptance over even or uneven terrain, maintaining balance, and efficiency during propulsion. Joint mobility and stability are provided through coordinated synergy of the extrinsic and intrinsic muscles of the ankle-foot complex (Figures 5.1-5.3).

Shank

Comprised of the tibia and fibula, the shank originates at the knee proximally and extends distally to the talocrural joint. Proximally, the fibula is supported by the anterior and posterior ligaments of the fibula head and forms the proximal tibiofibular joint. The interosseous ligament joins the tibia and fibula diaphysis to form a syndesmosis. Distally, the fibula articulates with the tibia to form the distal tibiofibular joint and is supported by the anterior and posterior tibiofibular ligaments. The distribution of mass borne through the shank is approximately 70% to 90% by the tibia and 10% to 30% by the fibula.[36] The shank is coupled to the rearfoot, with rearfoot pronation motion and shank internal rotation occurring together during loading, and, conversely, rearfoot supination and shank external rotation occurring during propulsion.[37]

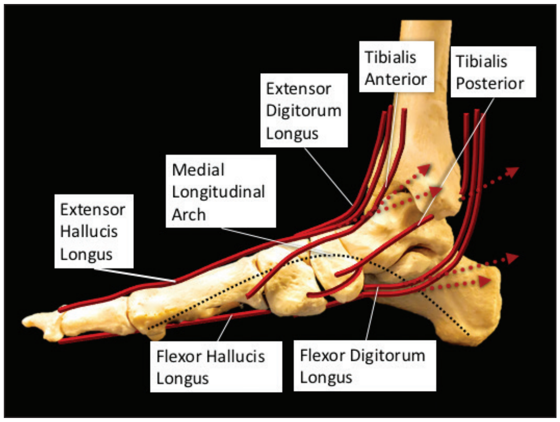

Figure 5.1. Morphology and extrinsic dynamic support of the medial longitudinal arch.*

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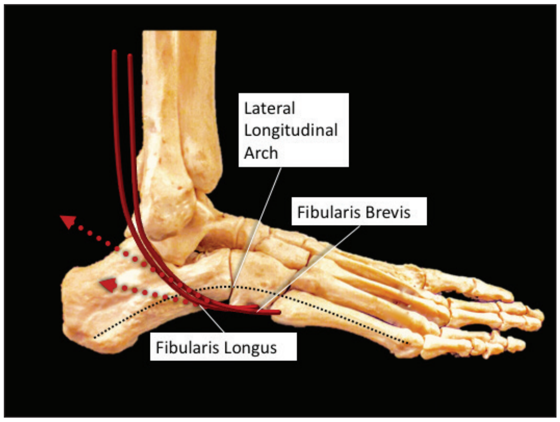

Figure 5.2. Morphology and extrinsic dynamic support of the lateral longitudinal arch.*

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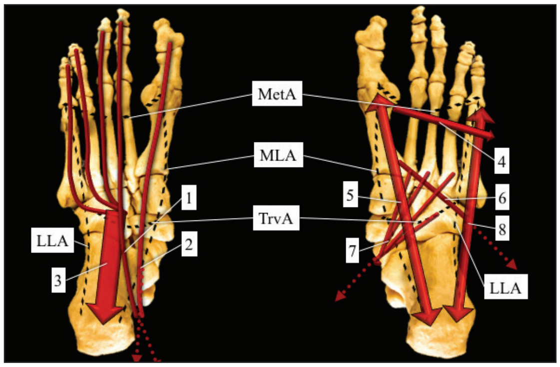

Figure 5.3. Morphology and dynamic support of the longitudinal and transverse arches (Plantar Aspect).* 1 = Flexor Digitorum Longus, 2 = Flexor Hallucis Longus, 3 = Quadratus Plantae, 4 = Adductor Hallucis, 5 = Abductor Hallucis, 6 = Fibularis Longus, 7 = Tibialis Posterior, 8 = Abductor Digiti Minimi, MLA = Medial Longitudinal Arches, MetA =Metatarsal Arches, LLA = Lateral Longitudinal Arches, TrvA= Transverse Arch.

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Rearfoot

The rearfoot is comprised of the talus and calcaneus. Proximally, the talus articulates with the tibia and fibula in a mortise and tenon configuration and forms the talocrural joint. The talocrural joint is supported by the deltoid ligament medially and the anterior talofibular, calcaneofibular, and posterior talofibular ligaments laterally. Distally, the talus articulates with the calcaneus and forms the subtalar joint. The subtalar joint is supported by the joint capsule and several ligaments. Internally, the cervical and interosseous talocalcaneal connect the talus and calcaneus, while externally the posterior talocalcaneal, lateral talocalcaneal, calcaneofibular, and fibular-talocalcaneal ligaments restrain the subtalar joint. The talocrural joint has an oblique axis of rotation that transects the medial and lateral malleoli[38] (Figure 5.4). Similarly, the subtalar joint has an oblique axis of rotation that result in triplanar motion of pronation, abduction, and dorsiflexion and supination, adduction, and plantar flexion[38] (see Figure 5.4). This triplanar orientation of the axes allows for the change of shank transverse plane motion to foot frontal plane motion during shank-rearfoot coupling.

Midfoot

The midfoot is comprised of the navicular, cuboid, and the 3 cuneiforms. The midtarsal (Chopart) joint complex is comprised of the talonavicular and the calcaneocuboid joints that join the rearfoot and midfoot. These joints are supported dorsally by the calcaneocuboid and calcaneonavicular ligaments (together forming the bifurcate ligament) and dorsal talonavicular ligament, medially by the tibionavicular ligament (part of the deltoid ligament), and on the plantar aspect by the plantar cuboid-navicular ligament and the spring ligament. The cuneiforms are supported by the dorsal and plantar inter-cuneiform ligaments. There are two axes of rotation, longitudinal and transverse, that transect the midfoot.[39] When decoupled, the longitudinal axis allows for forefoot frontal plane (inversion and eversion) motion to occur independent from the rearfoot.[39] On the oblique axis, the cuboid translates medially and locks to form a mechanical coupling between the rearfoot and forefoot.[40]

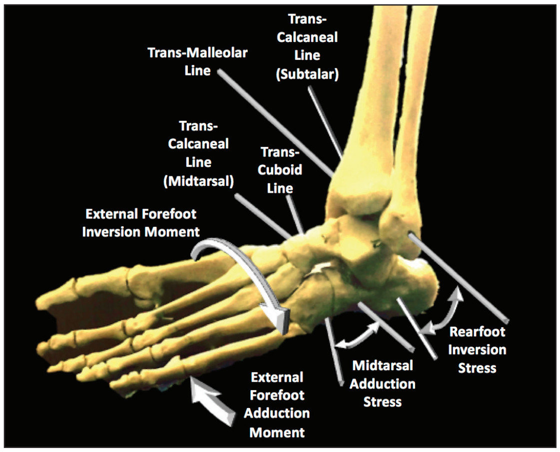

Figure 5.4. Lateral midfoot stress due to external adduction and inversion moments during an inversion injury.*

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Forefoot

The forefoot consists of the metatarsals and the phalanges and is functionally divided into the medial forefoot (first metatarsal and the great toe) and the lateral forefoot (metatarsals and toes 2-5). Independent and coupled triplanar motions of forefoot inversion and eversion occur about the midfoot. The first tarsometatarsal and Lisfranc articulations join the forefoot and midfoot and are supported by the dorsal and plantar tarsometatarsal, intermetatarsal, and Lisfranc ligaments. Together with the medial midfoot, the 1st metatarsal forms the distal truss of the medial longitudinal arch (see Figure 5.1). The hallux is comprised of the proximal and distal phalanges, joined at the interphalangeal joint of the great toe. The hallux is joined to the medial truss by the 1st metatarsophalangeal joint and is supported by the joint capsule and the plantar, medial collateral, and lateral collateral ligaments.

Foot Architecture

The foot has 4 distinct arches that enable deformation and accommodation to uneven terrain, attenuation of force during weight acceptance, and formation of a rigid lever required for efficient propulsion during walking, running, and jump landing. The largest and most distinct arch is the medial longitudinal arch (see Figure 5.1). This arch is formed by the calcaneus, medial midfoot and forefoot, and is oriented about the long axis of the foot. The less prominent lateral longitudinal arch is formed by the calcaneus, cuboid, and 5th metatarsal (see Figure 5.2). The longitudinal arches provide the capacity to functionally lengthen and shorten the foot during loading. Perpendicular to the long axis, the proximal and distal transverse arches are formed by the "Roman arch" of the bones of the midfoot and the metatarsals (see Figure 5.3). The transverse arch allows for the foot to splay or widen. As a functional whole, the morphology of the foot forms what has been described as a "half-dome"[41,42] that allows the foot to deform in 3 dimensions. Foot morphology is dynamic and, in addition to the stretching and recoiling of the bones, plantar ligaments, and plantar fascia, is controlled through an interplay of both intrinsic[41,43–48] and extrinsic[47–49] muscle activity.

EXTRINSIC MUSCLES OF THE ANKLE-FOOT COMPLEX

The extrinsic muscles of the ankle-foot complex have an important role in joint mobility and stability during function. These muscles function as prime movers and as conjoint, neu-