T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF SPORTS PHYSIOTHERAPY

THE EFFECTS OF UNILATERAL BALANCE TRAINING ON BILATERAL BALANCE AND EXPLOSIVE POWER AMONG ATHLETES WITH CHRONIC ANKLE INSTABILITY

MASTER THESIS

AYÇA YAĞCIOĞLU, PT, MSc

ISTANBUL, 2019

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated 31.07.2019..... and numbered 2019/13-02

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgement has been made in the text.

Ayça YAĞCIOĞLU

DEDICATION

I would like to dedicate my thesis to my beloved sisters Gökçe and Tuğçe Yağcıoğlu.

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LIST OF SYMBOLS AND ABBREVIATIONS

Δ	Post Variables minus Pre Variables
AITFL	Anterior Inferior Tibiofibular Ligament
ANOVA	Analysis of Variance
ATFL	Anterior Talofibular Ligament
BESS	Balance Error Scoring System
BMI	Body Mass Index
CAI	Chronic Ankle Instability
CAIT	Cumberland Ankle Instability Tools
CFL	Calcaneofibular Ligament
CG	Control Group
CMJ	Countermovement Jump
CNS	Central Nervous System
FAAM-ADL	Foot and Ankle Ability Measure – Activity of Daily Living
FAAM-S	Foot and Ankle Ability Measure – Sports
FI	Functional Instability
FTCL	Fibulotalocalcaneal Ligament
HSD	Honestly Significant Difference
KAİ	Kronik Ayak Bileği İnstabilitesi
LAS	Lateral Ankle Sprain
LTCL	Lateral Talocalcaneal Ligament
MRI	Magnetic Resonance Imagination
NMC	Neuromuscular Control
OARs	Ottawa Ankle Rules
PITFL	Posterior Inferior Tibiofibular Ligament
PTFL	Posterior Talofibular Ligament
RICE	Rest, Elevation, Ice, Immobilization
ROM	Range of Motion
SD	Standard Deviation
SEBT	Star Excursion Balance Test
SG	Rehabilitation for Stable Ankle Group
SPSS	Statistical Package for Social Science

UG	Rehabilitation for Unstable Ankle Group
VJ	Vertical Jump
YBT	Y Balance Test

ABSTRACT

Yağcıoğlu, A. (2019). The Effects of Unilateral Balance Training on Bilateral Balance and Explosive Power Among Athletes with Chronic Ankle Instability, Yeditepe University, Institute of Health Sciences, Department of Sports Physiotherapy, Master Thesis. Istanbul.

The aim of the study is to investigate the effects of a 4-week, unilateral balance exercise training program on bilateral balance and explosive power in athletes with chronic ankle instability (CAI). The study included 28 volunteer athletes with a history of CAI (15F, 13M; 20.96±1.50 years) who registered as a team player at Yeditepe University Culture and Sports Directorate December 2018 - May 2019. The severity of functional ankle instability of all the athletes was assessed by the Cumberland Ankle Instability Tool (CAIT). Functional limitations of the athletes with CAI were evaluated by Foot and Ankle Ability Measure Activity of Daily Living Subscale (FAAM-ADL) and Sports Subscale (FAAM-S). Balance Error Scoring System (BESS) was used to determine the static balance performance of athletes. Dynamic balance was evaluated by the Y Balance Test (YBT). Sport performance including vertical jumping and hopping was assessed with Single-Legged Countermovement Jump (CMJ) Test, Figure-of-Eight Hop Test, and Side Hop Test. The athletes were randomly divided into Rehabilitation for the Stable Ankle Group (SG) (n=9), Rehabilitation for the Unstable Ankle Group (UG) (n=9) and Control Group (CG) (n=10) Athletes in SG and UG were included balance exercise training program. The balance exercise training program was administered for only the stable ankle of athletes in SG and only the unstable ankle of athletes in UG, twice a week and for a 4-week duration. According to the main results of this study comparing three groups, SG and UG showed greater improvement in FAAM-ADL, FAAM-S, BESS, YBT, CMJ, Figure-8 Test and Side Hop Test values ($p<0.01$ for both SG and UG). Consistent with the hypothesis, our findings suggest that the balance exercise training only applied to the stable ankle may provide improvements in terms of functionality, static and dynamic balance and explosive power on the unstable ankle of athletes with CAI.

Key Words: ankle, joint instability, athlete, cross-education, balance, rehabilitation

ÖZET

Yağcıoğlu, A. (2019). Kronik Ayak Bileği İnstabilitesi Olan Sporcularda Unilateral Denge Eğitiminin Bilateral Denge ve Patlayıcı Güç Üzerine Etkisi, Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Spor Fizyoterapisi Anabilim Dalı, Yüksek Lisans Tezi. İstanbul.

Bu çalışmanın amacı, kronik ayak bileği instabilite (KAİ) geçmişi olan sporcularda 4 haftalık, tek taraflı denge egzersiz eğitimi programının iki taraflı denge ve patlayıcı güç üzerindeki etkilerini araştırmaktır. Çalışmaya Yeditepe Üniversitesi Kültür ve Spor Müdürlüğü'nde Aralık 2018 - Mayıs 2019'da takım oyuncusu olarak kayıtlı kronik ayak bileği instabilite (KAİ) (15K, 13E; 20.96 ± 1.50 yıl) geçmişi olan 28 sporcu dahil edildi. Tüm sporcuların ayak bileği fonksiyonel limitasyonları Cumberland Ayak Bileği İnstabilite Anketi (CAIT) tarafından değerlendirildi. KAİ'li sporcuların fonksiyonel kısıtlılıkları, Ayak ve Ayak Bileği Kullanılabilirlik Ölçüsü Günlük Yaşam Alt skalası (FAAM-ADL) ve Spor Alt skalası (FAAM-S) ile değerlendirildi. Sporcuların statik denge performansını belirlemek için Denge Hata Puanlama Sistemi (BESS) kullanılmıştır. Dinamik denge Y Denge Testi (YBT) ile değerlendirildi. Dikey sıçrama ve yatay sıçramaların dahil olduğu spor performansı Tek Bacak Countermovement Sıçrama Testi (CMJ) Testi, Şekil-Sekiz Sıçrama Testi ve Yana Sıçrama Testi ile değerlendirildi. Sporcular, randomize bir şekilde Stabil Ayak Bileği Rehabilitasyonu Grubu (SG) (n = 9), İnstabil Ayak Bileği Rehabilitasyonu Grubu (UG) (n = 9) ve Kontrol Grubu (CG) (n = 10) olmak üzere üç gruba ayrıldı. SG ve UG grubundaki sporcular denge egzersiz eğitimi programına dahil edildi. Denge egzersizi eğitim programı, SG'deki sporcuların sadece stabil ayak bileği, UG'deki sporcuların ise sadece instabil ayak bileği için 30 dakika haftada iki kez ve 4 haftalık bir süre boyunca uygulandı. Üç grubu birbiriyle karşılaştıran bu çalışmanın ana sonuçlarına göre, SG ve UG, FAAM-ADL, FAAM-S, BESS, YBT, CMJ, Şekil-8 Testi ve Yana Sıçrama Testi değerlerinde benzer gelişmeler göstermiştir (her iki grup için $p < 0.01$). Hipotezle uyumlu olarak, bulgularımız sadece stabil ayak bileğine uygulanan denge egzersizi eğitiminin, KAİ'li sporcuların instabil ayak bileğinde işlevsellik, statik ve dinamik denge ve patlayıcı güç açısından gelişmeler sağlayabileceğini göstermektedir.

Anahtar Kelimeler: ayak bileği, eklem instabilitesi, sporcu, çapraz eğitim, denge, rehabilitasyon

1. INTRODUCTION AND PURPOSE

The ankle is one of the most injured joints in sports activities. Ankle injuries account for 10–30% of all sports injuries. Among musculoskeletal injuries, the ankle sprain is one of the most frequent encountered sports injuries responsible for about 80% of all ankle injuries (1,2). 85% of ankle sprains are seen as lateral ankle sprains (LAS) (3). 73% of lateral ankle sprain is considered to be caused by tear or rupture of ATFL (1,4). Between 1977 and 2005, the systemic review of 227 epidemiological studies involving 70 sports in 38 countries demonstrated that 11 847 of 32 509 ankle injuries included ankle sprains. In all ankle injuries, the occurrence rate of ankle sprain is reported to be about 99% for volleyball, 91% for basketball and 100% for handball players (1).

The most frequent injury mechanism of lateral ankle sprains is excessive inversion, internal twisting and plantar flexion of the foot associated with external rotation of the lower leg (5,6). In sports, injuries most frequently happen throughout jumping, forward pushing or cutting maneuvers especially lateral cutting movements which are very common particularly in volleyball, basketball (2).

After the acute sprains, chronic ankle instability (CAI) develops in proportion as 20–40% of cases that do not include appropriate treatment with strong evidence strategies such as bracing and neuromuscular training (6,7). CAI is the term describing cases indicating residual symptoms of instability and a sensation of “giving away” that continues 12 months following the first ankle sprain (6).

Patients with CAI demonstrate several types of deficits consisting of decreased range of motion (ROM) of the ankle (6), quality of ankle arthrokinematic motion (8), postural control (8–10) and strength (6,10,11), impaired proprioception and neuromuscular control (6,10,12) and altered gait patterns (6). It is claimed that neuromuscular functions have changed after the initial LAS due to damage to the ankle ligament mechanoreceptors providing proprioceptive input and the peroneal nerve (12).

Neuromuscular control (NMC) comprises the subconscious processing of sensory information in the central nervous system (CNS) and the control of muscle movement throughout coordinated muscle activity (13). The role of NMC is to facilitate and maintain postural control and functional joint stability by providing dynamic restraints during joint motion and loading (14). Any injury causing the damage of the mechanoreceptors, changes in normal sensory input and impedes of the processing of sensory information may cause altered NMC and consequently, result in injury or dysfunction in postural control and dynamic joint stability and also functional ankle instability (13–15). Even if healing is observed after injury, the function of mechanoreceptors may not be recovered, causing NMC deficits that may lead to CAI. Also, the level of damage to the receptors and alterations in CNS processing may contribute to CAI. Some reports have suggested that after LAS, bilateral postural control deficits occur with suggesting a central impairment in NMC. In addition, some researchers observed bilateral improvements in NMC following rehabilitation for CAI (15,16). Thus, NMC is not only controlled by peripheral mechanoreceptors but also adaptations in the central pathways may partly cause deficits after an ankle sprain.

According to the Cochrane review (2011), neuromuscular training provides short-term improvement for CAI-related symptoms (6). A recent study demonstrated that the ankle positions of athletes with CAI were relatively inversion and that the ankle orientation changed toward minimally an everted direction after 6 weeks of neuromuscular training (17). Cruz-Diaz et al. claimed that balance training exercises based on multi-station tasks significantly improved the self-reported sensation of instability and dynamic balance in individuals with CAI (18). O'Driscoll et al. also indicated that the 6 weeks of dynamic neuromuscular exercise training led to improvements in sensorimotor control of ankle joint of athletes with CAI (19). Hale et al. claimed that positive effects in dynamic balance and lower limb function may be seen on the unstable ankle side following balance exercises for the stable ankle (15).

The exercise training for only the stable ankle in individuals with CAI may lead to postural control improvements on the unstable ankle when considering the bilateral deficits following the unilateral injury. Therefore, clinicians are likely able to early begin neuromuscular training including the stable ankle rehabilitation as a part of the comprehensive rehabilitation strategy for individuals or athletes with CAI to avoid losing time, lower extremity functions and sports performances. Many athletes return to sports within 15 days even with many reporting pain and deficits in function and postural control after an acute LAS (16). Researchers (20) also suggested that neuromuscular training should be started after the pain and weight-bearing restrictions are removed. Thus, the time spent to restore postural stability before returning to sports is minimal, possibly resulting in increased risk for re-injury and residual dysfunction among athletes. By starting NMC training earlier, it is possible for athletes to return to sports without loss of function and ready for the functional requirements of the sport. Therefore, the aim of this study was to investigate the effects of a 4-week, unilateral balance exercise training program including balance and hop-stabilization exercises for stable or unstable ankle on the bilateral balance and explosive power among athletes with CAI.

Two hypotheses identified in the study:

H0: Balance exercise training applied to only the stable ankle has similar improvements in terms of physical function, static and dynamic balance, and sports performance compared to the balance exercise training applied to only the unstable ankle among athletes with CAI.

H1: Balance exercise training applied to only the stable ankle has no similar improvements in terms of physical function, static and dynamic balance, and sports performance compared to the balance exercise training applied to only the unstable ankle among athletes with CAI.

2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1. Anatomy and Biomechanics of the Ankle

The ankle complex is composed of the talocrural, subtalar and distal tibiofibular syndesmosis joints. The alignment of these joints is necessary for coordinated triplanar motions of the rearfoot in main cardinal planes; sagittal plane (plantar and dorsiflexion), frontal plane (inversion and eversion), transverse plane (internal and external rotation) movements (5,21,22).

Mechanically, the rearfoot movement does not occur in isolation, however, rather in the synchronized movement of these joints allow the rearfoot to move around an oblique axis of rotation. The rearfoot does not move completely in cardinal planes due to the oblique axes of rotation of the talocrural and subtalar joints. Pronation and supination as coupled rearfoot motion are combined calcaneal motions. In the open kinetic chain, pronation comprises eversion, dorsiflexion and external rotation whereas supination comprises inversion, plantarflexion, and internal rotation. Pronation in the closed kinetic chain comprises eversion, plantar flexion, and external rotation, whereas supination comprises inversion, dorsiflexion, and internal rotation (23–25).

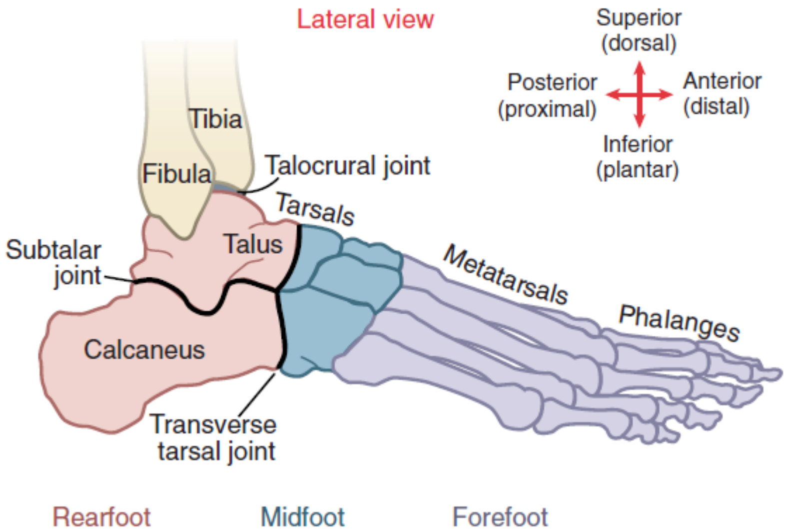


Figure 1.1 The overall association of the bones and the main joints of the foot and ankle (24).

2.1.1 Talocrural Joint

The talocrural joint articulation consists of the trochlea of the talus, the tibial plafond, the medial and lateral malleolus (Figure 1.1, 1.2) (24,26).

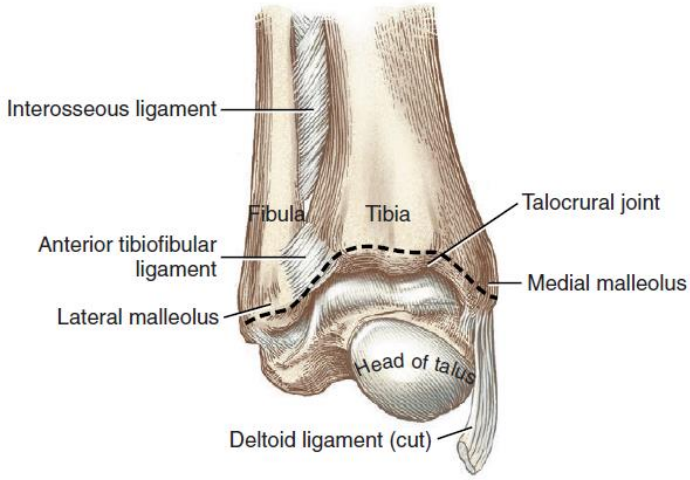


Figure 1.2 An anterior view of the articulation of the distal part of the right tibia and fibula and the talus forms the talocrural joint (24).

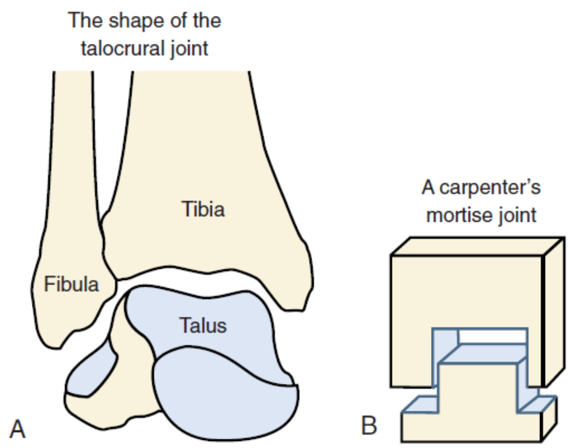


Figure 1.3 The similarity between the talocrural joint (A) and a mortise joint (B) is shown (24).

The shape of the talocrural joint permits transfer of the torque from the lower limb to the foot through weight-bearing (25). Due to the similarity to the wooden joint used by carpenters, the joint is frequently referred to as the "mortise" (Figure 1.3) and can be considered as a hinge joint that provides plantar flexion and dorsiflexion movement in isolation. Movement occurs around the rotational axis of the talocrural joint passing throughout the talar body and the apexes of both malleoli. The lateral malleolus is positioned more inferiorly and posteriorly than the medial malleolus. This axis is slightly in the superior and anterior as it passes lateral to medial across the talus but slightly in the posterior as it passes throughout both malleoli. Isolated motion of the talocrural joint is mainly in the sagittal plane. Furthermore, the horizontal and frontal plane motions occur around the oblique rotation axis (21,24–26). The axis deviates from the medial to lateral axis approximately 6˚ in the horizontal plane and 10˚ in the frontal plane (Figure 1.4). Therefore, dorsiflexion is accompanied by slight abduction and eversion while plantar flexion is accompanied by slight adduction and inversion (24). The articular surfaces of the talocrural joint are the main stabilizer against excessive rotation of the talus and translation in the loaded ankle. Besides, the unloaded ankle is stabilized with the integration of several ligaments, joint capsule, and musculotendinous units (21,25).

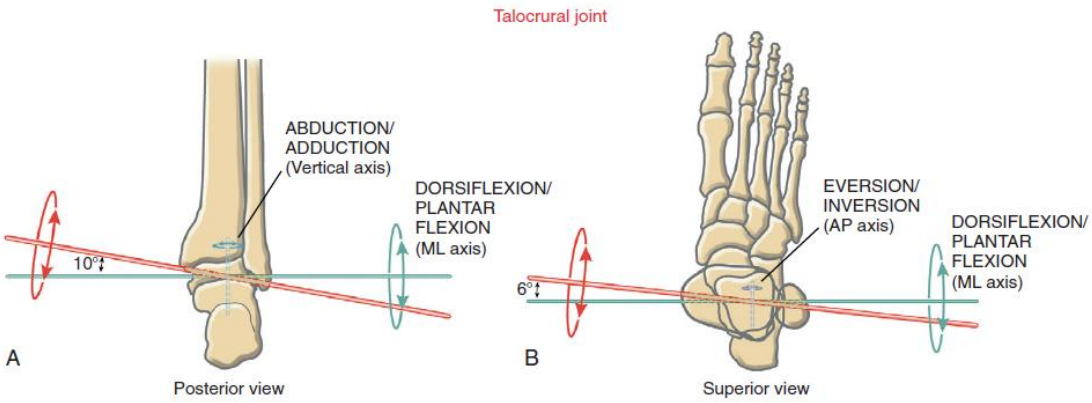


Figure 1.4 The oblique axes of rotation are demonstrated from posterior (A) and superior (B) (24).

The talocrural joint is enclosed by a thin capsule externally supported by collateral ligaments involving the anterior talofibular ligament (ATFL), calcaneofibular ligament (CFL), posterior talofibular ligament (PTFL) and deltoid ligament. The ATFL, PTFL, and CFL provide support for the lateral part of the ankle, while the deltoid ligament support the medial side of the ankle (21,24,25).

The ATFL adheres to the anterior side of the lateral malleolus, runs in a anterior and medial direction towards the talar neck and shows a 44.8º angle from the frontal plane (Figure 1.5.) (24,27). The ATFL has an average width of 7.2 mm, a length of 24.8 mm and a thickness of 2 mm (27,28). The role of the ATFL is to limit excessive inversion and internal rotation of talus in relation to the tibia and anterior transposition of the talus from the mortice (25). The ATFL has 2 – 3.5 times lower energy to failure and maximal load durability than the CFL, PTFL and deltoid ligament when exposed to tensile stresses (21,25). Therefore, the ATFL is the most often damaged ligament among the lateral ligaments. Injury mostly occurs as a result of excessive inversion, particularly when combined with plantarflexion which is the tautest position for the ATFL (22,24).

The CFL courses posteriorly and inferiorly from the tip of the lateral malleolus to the tubercle on the lateral surface of the calcaneus at an angle between 133˚and 150˚with the fibula (Figure 1.5.) (24,27). The average width of this CF ligament is 5.3 mm and the average length is 35.8 mm (27). It lies underneath the peroneal tendons (28). The role of the CFL is to resist excessive inversion through the talocrural joint and the subtalar joint and is under most tension in the dorsiflexed ankle (24,25). The CFL and ATFL as a pair, restrict inversion through most of the ROM of plantar flexion and dorsiflexion. Approximately two-thirds of lateral ligament injuries contain both of these ligaments (24).

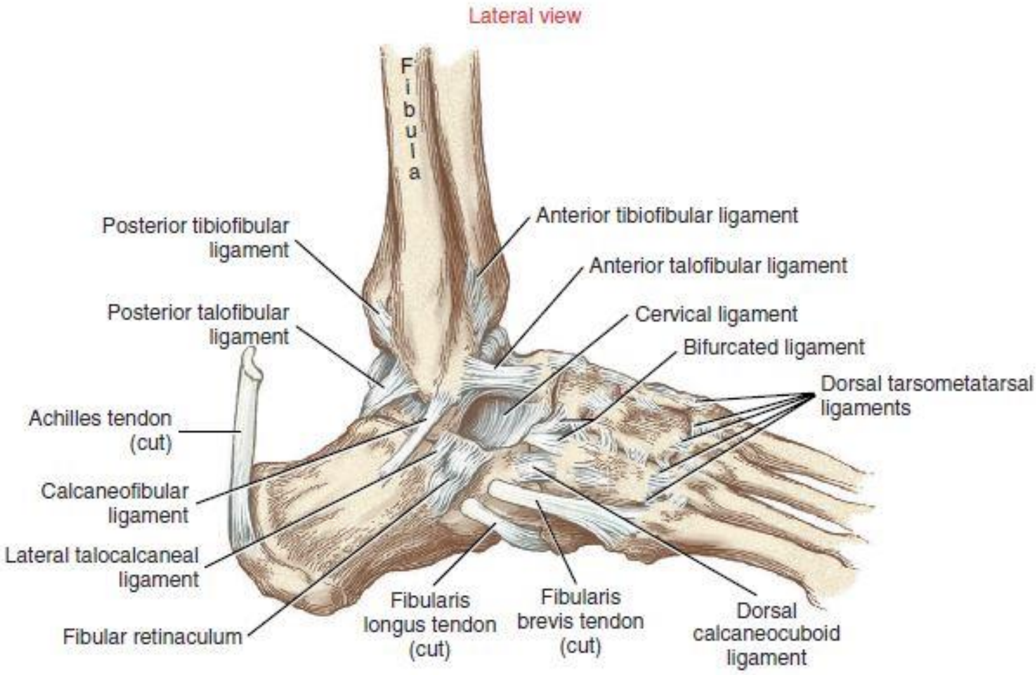


Figure 1.5 Lateral collateral ligaments of the right ankle.

The PTFL originates on the posteromedial aspect of the lateral malleolus and inserts on the lateral tubercle of the talus (Figure 1.5) and runs horizontally across the posterior aspect of the talus in the posteromedial direction (Figure 1.6, and 1.10). The main function of the PTFL is to provide stability for the talus within the mortise. It provides restraint to excessive abduction of the talus, particularly in dorsiflexion (24). The ligament has the least rate of isolated injuries among the lateral ankle ligaments.

Mostly, PFT ligament injuries occur in consequence of severe ankle sprains with rupture of both ATFL and CFL (25,28).

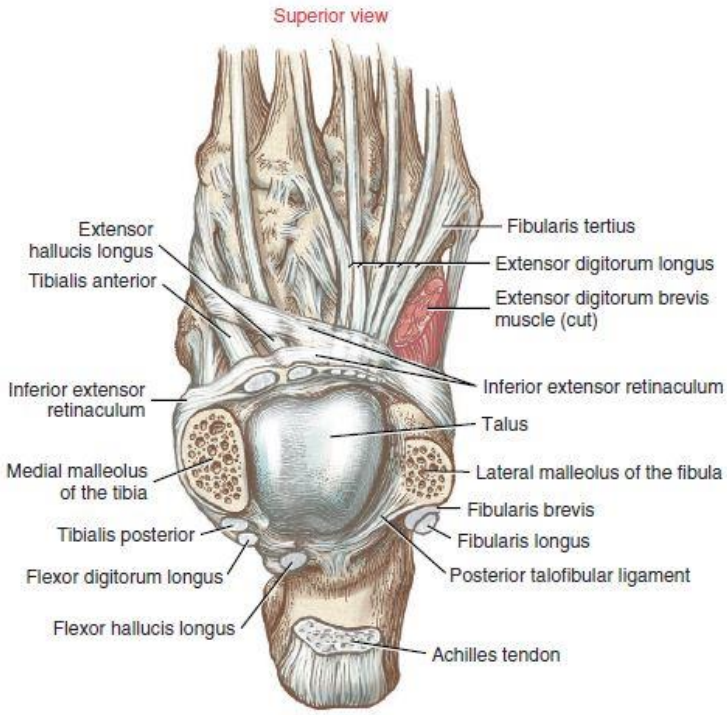


Figure 1.6 A superior view of the right talocrural joint. Both malleoli and all the tendons are cut (24).

The medial collateral ligament, called the deltoid ligament due to its triangular shape contains superficial and deep layers (Figure 1.7 and 1.10). The deltoid ligament originates from the apex of the medial malleolus and spreads following the strongest and deeper fibers called the posterior tibiotalar part runs inferiorly and posteriorly and attachs to the medial surface of talus, the tibiocalcaneal part inserts into the sustentaculum tali of the os calcis, the tibionavicular part attaches to the navicular bone (21,24,29). The deeper tibiotalar fibers play a key role in ankle stability by strengthening the medial capsule of the talocrural joint (22,24). This strongest ligament with a tensile strength of 714 N among the lateral ankle ligaments provides restraint against talar shift in the direction of abduction and lateral translation (22,30). Relatively, the deltoid ligament is rarely sprained because of its strength and lateral malleolus acting as a bony block (24).

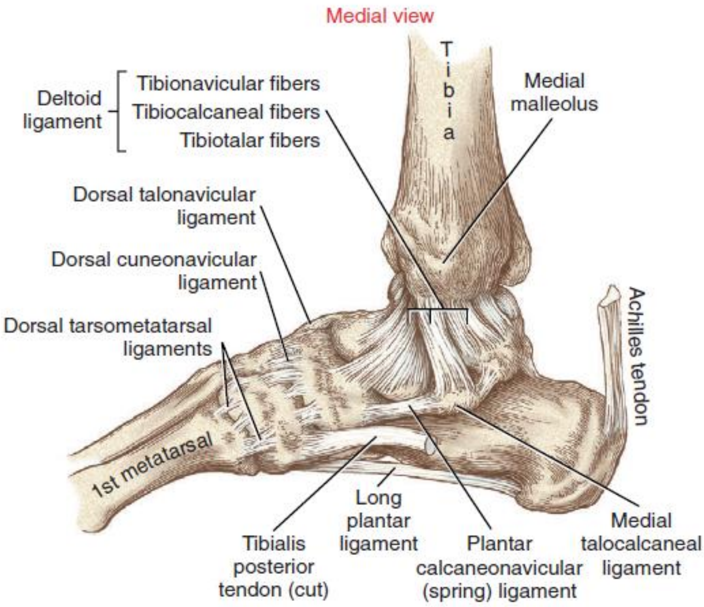


Figure 1.7 Medial view of the right ankle ligaments are demonstrated (24).

2.1.2 Subtalar Joint

The subtalar joint is a complex structure formed by two articulations between the anterior and posterior facets of the calcaneus and the talus. The joint transfers torque from the lower limb to the foot like the talocrural joint. The posterior part consists of the concave inferior superior facet of the talus and the convex superior posterior facet of the calcaneus. This articulation occupies approximately 70% of the articular surface region. The anterior articulation consisting of nearly flat, smaller joint surfaces consist of the concave surface of the navicular, the convex head of the talus, the anterior superior facets and the sustentaculum tali of the calcaneus. This articulation acts like a ball and socket joint. While the head of the talus represents the ball, the proximal navicular and anterior calcaneal surfaces form the socket. The anterior articulation lies medially and has a higher axis of rotation than the posterior articulation. The axis of rotation is situated 42° on the horizontal plane and 16° on the sagittal plane (Figure 1.8, A-B). Considerable variation exists in the degrees of the axis of rotation from person to person. Pronation and supination movements are provided while the calcaneus move relative to the talus in a perpendicular arc to the axis of rotation (23–25).

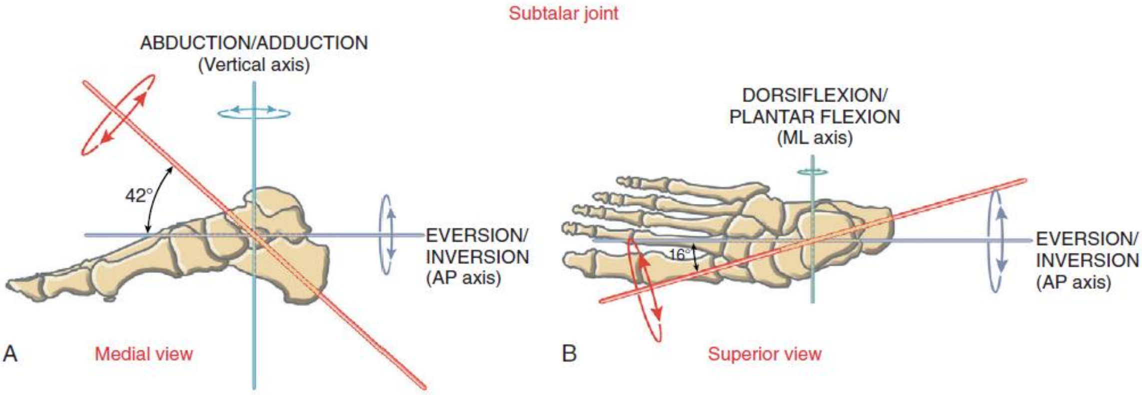


Figure 1.8 The axes of rotation of the subtalar joint are demonstrated from the medial (A) and superior (B) (24).

The division between the anterior and posterior articulations is formed by the tarsal canal and the sinus tarsi. These articulations are each enclosed by a articular capsule including synovial membrane and fibrous capsule. The capsule is largely supported by medial, lateral and posterior talocalcaneal ligaments, serving as secondary stabilizers for the subtalar joint. Others classified as the deep and peripheral ligaments are the primary stabilizers for the joint as a whole (23–25).

The CFL which is one of the peripheral ligaments limits excessive inversion and internal rotation while the deltoid ligaments limit excessive eversion and external rotation of the calcaneus. The other peripheral ligaments include the lateral talocalcaneal (LTCL) and fibulotalocalcaneal (FTCL) ligaments. The LTFL and FTCL ligaments assist in resisting extreme motion of supination of the subtalar joint (23–25).

The deep ligaments including the cervical and interosseous ligaments insert between the talus and calcaneus. Thus, these ligaments provide nonmuscular stability to the subtalar joint and make a barrier that seperates the anterior and posterior joint capsules. The role of these ligaments are to limit the excessive motions, mostly notable inversion (23–25).

Injuries of the subtalar joint occur along with injuries to the lateral ligament of the talocrural joint. Isolated subtalar joint injuries rarely occur. Approximately %10 of chronic ankle instability accompany subtalar instability (28).

2.1.3 Distal tibiofibular joint

The distal tibiofibular joint referred to as a syndesmosis by anatomists articulates with the lateral side of the distal tibia called as the fibular notch and the medial surface of the distal fibula (Figure 1.9). A thick interosseous membrane which permits relatively slight movement between the tibia and fibula surrounds this joint. The gliding of the joint is essential to normal biomechanics through the complete ankle complex. There are three major ligaments; the interosseous ligament (Figure 1.10), the anterior inferior tibiofibular ligament (AITFL) (Figure 1.2) and the posterior inferior tibiofibular ligament (PITFL) (Figure 1.10) (24,25,31).

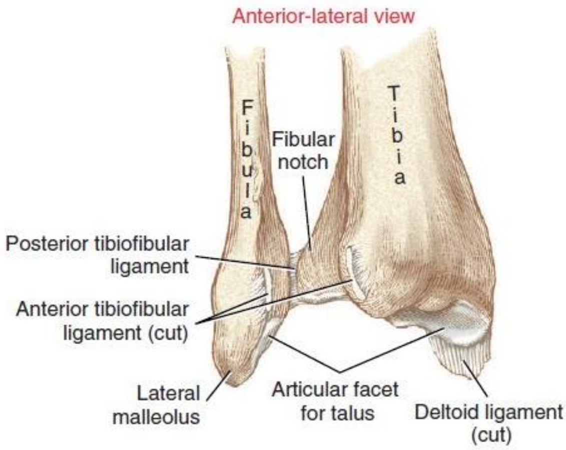


Figure 1.9 An anterolateral view of the right distal tibiofibular joint is demonstrated (24).

The ankle mortise is stabilized by these ligaments that provide dynamic support and allow the fibula to strongly resist the fibular notch. This structural integrity of two bones is crucial to the function of the talocrural joint. The interosseous tibiofibular ligament, an continuation of the distal interosseous membrane serves as a stabilizer and provides the strong bond between the distal tibia and fibula. The AITFL and PITFL primarily stabilize the distal tibiofibular joint. These ligaments act as a constraint to excessive external rotation of the foot and excessive motion of the distal fibula on the tibia. The AITFL which is known to be weaker than the PITFL is common injured in eversion position and eventuate in the high ankle sprain (24,25,31).

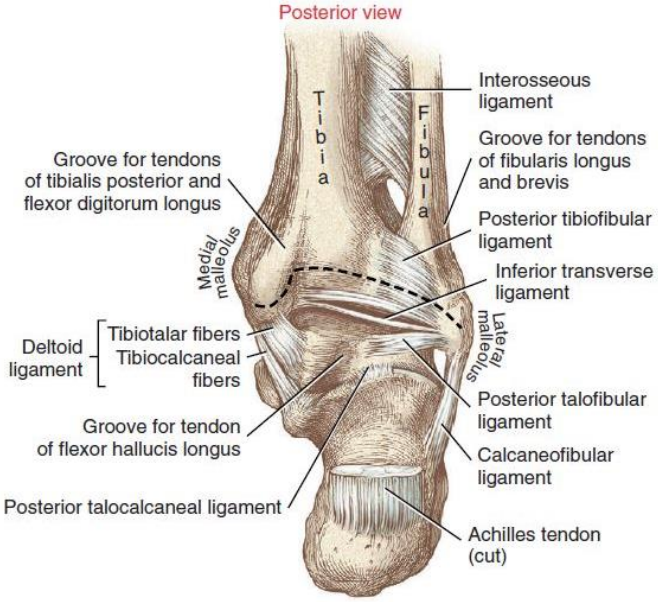


Figure 1.10 Posterior view of certain ligaments of the right ankle joints are demonstrated (24).

2.1.3. Muscles and Tendons

The ankle joint is supported by lower leg muscle and tendon groups. The muscles of the ankle and foot control the specific motions of the joints. Moreover, these muscles provide the stability, thrust and shock absorption which are necessary for locomotion. The majority of movement of the ankle and foot is produced by twelve extrinsic muscles which originates from the leg and inserts into the foot. These extrinsic muscles are divided into four compartments (Figure 1.11). The anterior compartment includes the tibialis anterior which is primary dorsiflexor of the talocrural joint and invertor of the subtalar joint, the extensor hallucis longus which produce dorsiflexion at the talocrural joint and extension at the phalanges of the hallux, extensor digitorum longus which extends the lateral four phalanges of the foot and the fibularis (peroneus) tertius which act as a dorsiflexor and evertor of the foot. The lateral compartment is comprised of the fibularis longus and the fibularis brevis which primarily evert the foot. The posterior compartment composes of the gastrocnemius, the plantaris and the soleus which are the primary plantar flexors of the ankle. Gastrocnemius also flexes the knee and participates in locomotion while soleus in posture. The deep posterior compartment includes the tibialis posterior, the flexor digitorum longus and the flexor hallucis longus which are the primary evertors of the foot. With the exception of the fibularis longus and brevis, all muscles in the posterior compartment plantarflex the talocrural joint and also invert the subtalar joint (Figure 1.12) (24,32).

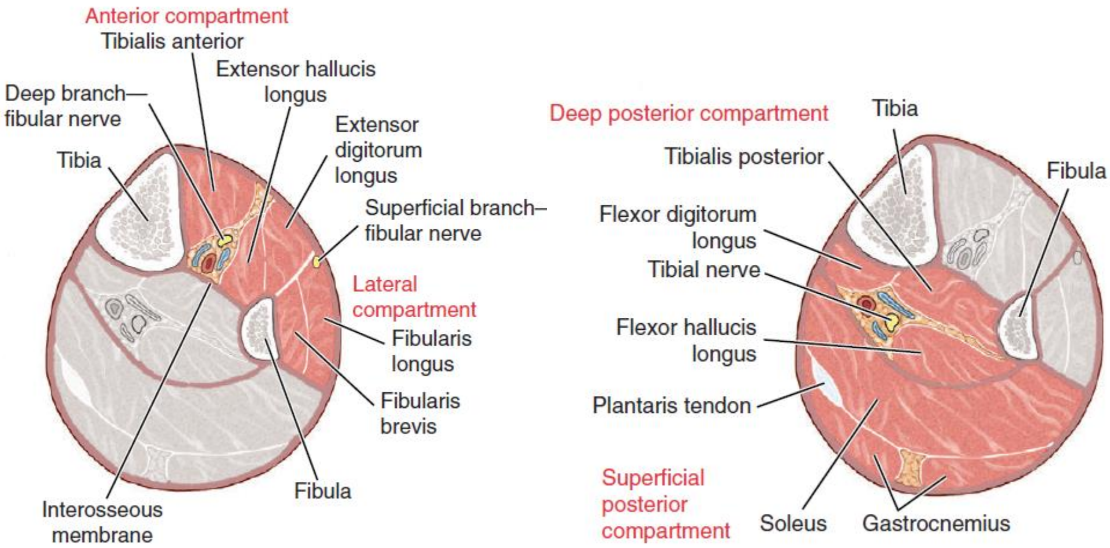


Figure 1.11 The cross-section of the muscles and nerves located within the anterior, lateral, superficial and deep posterior compartments of the lower leg are demonstrated (24).

Muscles work as concentric or eccentric based on their different actions. The muscles surrounding the ankle complex are frequently defined on the basis of their concentric actions but dynamic stability of joints is provided by eccentric functions of the muscles. The fibularis longus and brevis are primarily involved in controlling the supination of the subtalar joint and protecting against lateral ankle sprains. Besides, the muscles of the anterior compartment are eccentrically contracted during forced supination of the subtalar joint and dynamically stabilize the lateral ankle complex. These muscles can prevent lateral ligament injuries by decelerating the plantarflexion component of supination (25).

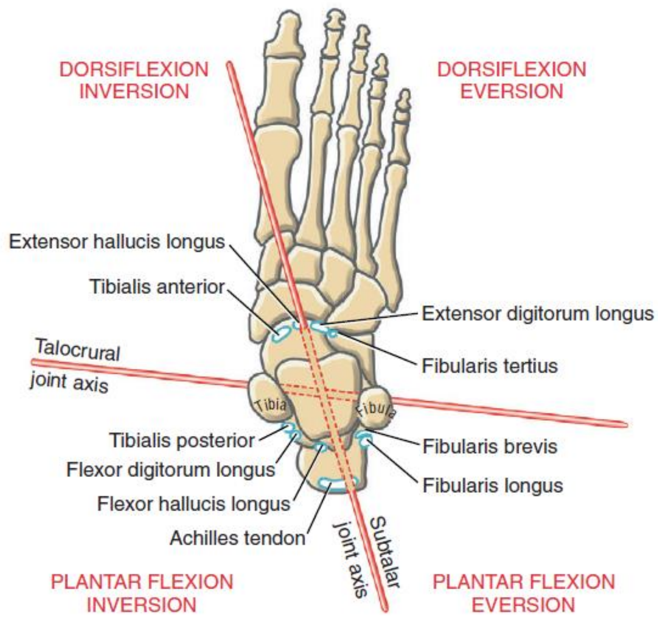


Figure 1.12 The actions of lower leg muscles based on their position in relation to the axes of rotation at the joints are demonstrated (24).

2.1.4. Innervation

Each motor nerve which innervates the muscles in all compartments is branched from the sciatic nerve stemmed from the L4-S3 spinal nerve roots of the sacral plexus. The motor supply comes from the common fibular and tibial nerves while the sensory supply stems from the common fibular, tibial, sural and saphenous nerves. The common fibular nerve (L4-S2) separates as a deep and superficial branch. The deep branch innervates the muscles of the anterior compartment. The talocrural joint receives sensory innervation from this branch. The superficial branch innervates the fibularis longus and brevis within the lateral compartment. The nerve also supplies sensory innervation to the skin on the dorsal and lateral surfaces of the leg and foot. The tibial nerve (L4-S3) and its terminal branches innervate the rest of the intrinsic and extrinsic muscles of the ankle and foot. A sensory branch of the tibial nerve reaches the medial side of the ankle and innerves the skin over the heel. The joint capsule and lateral ligaments of the talocrural and subtalar joints are innervated by mechanoreceptors which are the specialized nerve endings regarded to provide proprioception. The muscle spindles in the fibularis muscles is a significant factor for proprioception of the ankle complex (24,25,33).

2.1.5 Kinematics of Ankle

The motion of the ankle is defined as the angle of rotation of the rearfoot on the tibia in three Cartesian axes including the anterior-posterior (x-axis), medial-lateral (y-axis) and inferior-superior (z-axis) directions. Rotational movement of the ankle in the Y-axis is dorsiflexion and plantar flexion while is defined as inversion and eversion in the X-axis and internal and external rotation in the Z-axis. In a normal unconstrained of the ankle joint, motions do not only occur in these axes (34). Due to the shape of the talar trochlea and constraints of soft tissues within the ankle, the foot is disposed to rotate on multiple instant centers rather than a single instant center (34–36). The primary motions of the talocrural joint are dorsiflexion and plantarflexion, whereas the primary motions of the subtalar joint are inversion and eversion. The internal and external rotation occurs with the combined movement of the talocrural and subtalar joint (34). Inversion and internal rotation occur together and are accompanied by slight plantar flexion. In the same way, eversion and external rotation occur together and are accompanied by slight dorsiflexion (34,37). Most of the rotational range of motion occurs between the neutral position and dorsiflexion in the transition from plantar flexion to dorsiflexion. The rotational range has been shown variable between 5˚ to 18˚ by some authors (29,36).

During plantar flexion, the talus rolls to posterior while at the same time sliding towards the anterior and makes 5˚- 6˚ of internal rotation or adduction. During dorsiflexion, the talus moves to anteriorly on the tibia as at the same time slide towards posterior and makes 5°- 6° of external rotation or an abduction (24,29,35). When the ankle is under full body load, the rotational motion of the talocrural joint on a vertical axis without flexion is associated with internal rotation of the tibia and external rotation of the talus (26,29). In the multi-axis dynamic system, the talus combines rolling motion with a sliding motion with abduction and adduction in the coronal plane. When the tibia is fixed, the talus makes pronation through dorsiflexion and supination through plantarflexion around the anteroposterior axis and the transverse axis. When the talus is fixed, the tibia makes external rotation throughout plantar flexion and internal rotation throughout dorsiflexion. The range of motion varies based on the typology of the radii of curvature of the talus (29,36).

In a Magnetic Resonance Imaging (MRI) study, the three-dimensional kinematics showed that the talus and calcaneus did not act together as a whole. The calcaneal-tibial supination occurs mostly at the talocrural joint with minimal rotations occurring at the subtalar joint (37).

The ankle joint moves approximately 70° in the sagittal line, 45˚- 50° of it is active plantar flexion and 15˚- 20° is active dorsiflexion (35). The ankle motion has a variable range from 20˚ to 60˚with approximately 30˚ for walking, 37˚for ascending and 56˚ for descending stairs (35,36). The maximum dorsiflexion at the stance phase of running is approximately 10˚ and plantar flexion is about 14˚ (35). The average maximum reaction force of ankle joint is about 4 to 7 times the bodyweight of normal people during walking. Moreover, the shear forces passing the ankle joint are approximately 80% of the body weight. These rotational forces are controlled by the muscles, tendon and tendon sheaths, ligaments and the talocrural surfaces under load (36).

Functional maximal joint stability is the position where the talocrural joint is dorsiflexed and the subtalar joint is everted with the calcaneal valgus. This position is gained in the climbing or squatting with maximum joint congruence. During walking and plantar flexion, the ankle has a tendency to instability (36).

2.2. Ankle Problems in Sports

All recreational activities and sports branches carry an inherent risk of injury. It is a natural result of forcing the physical limits of the body and getting involved in challenging competition. Foot and ankle injuries constitute the majority are common among athletes in competitive and recreational sports. As most sports-related injuries, management requires functional rehabilitation and early return to sports or functional activity to perform at maximum performance with minimizing the risk of injury and avoiding long-term results. Therefore, timing in sports is a priority such that injury prevention and prognosis before the injury, and early diagnosis and treatment in the presence of injuries are often given importance. Intrinsic and extrinsic factors may provide the predisposition to injuries for athletes who are especially in running, jumping and cutting sports and may also affect the type and severity of injuries in the foot and ankle. Common sports-related pathologies and soft tissue injuries of the foot and ankle consist of ankle sprains, syndesmotic injuries, midfoot sprains, Lisfranc injuries, turf toe injuries, tendon ruptures and overuse syndromes (Achilles tendonitis, tibial stress syndrome or stress fractures) (38–40).

2.2.1. Ankle Sprain

The ankle is one of the most injured joints in sports activities. Ankle injuries account for 10–30% of all sports injuries. Among musculoskeletal injuries, the ankle sprain is most frequently encountered sports injuries accounting for about 80% of all ankle injuries and even more responsible in some sports (1,2). 85% of ankle sprains which account for 16-21% of all athletic injuries are seen as lateral ankle sprains (LAS) (3,41). 73% of lateral ankle sprain is considered to be caused by tear or rupture of ATFL (1,4). Between 1977 and 2005, the systemic review of 227 epidemiological studies involving 70 sports in 38 countries demonstrated that 11 847 of 32 509 ankle injuries included ankle sprains. In all ankle injuries, recurrence rate of ankle sprain is reported to be about 99% for volleyball, 91% for basketball and 100% for handball players (1).

The ankle sprain injuries are particularly widespread in sports branches requiring frequent jumping, pivoting and cutting maneuvers such as basketball, volleyball, handball, and football. Ankle sprains mostly result in pain, dysfunction, disability, the loss of activity, treatment requirement, and economic burden. Besides, a sprained ankle is prone to be reinjured with recurrent ankle generally leading to chronic instability (42).

There are 3 main ligamentous ankle injury classifications comprising lateral, medial, and syndesmotic ankle sprains. LAS are responsible for approximately 88% of all ligamentous ankle injuries, while 6.7% for medial and 5.1% for syndesmotic ankle injuries. Ligamentous ankle injuries are mostly common in adolescents with 15-19 years of age and young adults. In general, no difference is found between men and women in terms of the occurrence of ankle sprains. Compared with other ethnicities, ankle sprains show slight predominance in Caucasians and African Americans (43).

2.2.1.1. Lateral Ankle Sprain

Lateral ankle injuries are more likely than medial-sided complaints that coincide with plantar flexion and foot inversion (44). Lateral ankle sprain (LAS) is frequently the result from damage of lateral collateral ligaments comprising ATFL, CFL, and PTFL. Residual symptoms after LAS have an effect on 55% to 72% of patients between 6 weeks to 18 months. The wide range of long-standing symptoms and frequency of complications following ankle sprain lead to the diagnosis of the 'sprained ankle syndrome'. The severity of ankle sprains is often considered insignificant by athletes and non-evidence-based treatment plans for LAS may be insufficient for residual symptoms and preventing recurrent injuries (25).

2.2.1.1.A. Pathomechanics

The ankle stability is vulnerable in plantar flexion and inversion position. Touching the ground in this position may give rise to a large supination torque overloaded and then damaged the lateral ankle ligaments by increasing the moment arm of the ground reaction force compared to the forces acting on the neutral or dorsiflexed ankle in both sagittal and coronal planes (Figure 1.13). Internal rotation of foot fixed the ground at various degrees of dorsiflexion of the ankle is another injury mechanism, while external rotation of the leg on the fixed ankle applies tensile stress on the ATFL (21,45). During this movement, the medial side of the shoe sole first contacts the ground and produces a large lever in relation to the subtalar joint axis. In this way, the large lever may lead to a large supination torque which produces the excessive foot inversion, overloades and then damages the lateral ankle ligaments (46).

The injury of ATFL is seen in 73% to 96% of LAS cases, whereas the CFL is injured in 80% (21). The combination injury involving both ruptures of the ATFL and CFL is stated as 20%. Isolated rupture of the CFL is very rare and rupture of the PTFL extremely rare without dislocation of the ankle joint (25,41,45).

Figure 1.13 Inversion position is the main mechanism of lateral ankle sprains (5).

2.2.1.1.B. Risk Factors

Multiple research reports have identified predispositions for ankle sprains in athletic cohorts classified as intrinsic or extrinsic factors. Intrinsic risk factors consist of age, gender, height, weight, body mass index (BMI), limb dominance, previous injury, increased tibial varum and talar tilt greater than 5 degrees (47), foot morphology especially wide foot, reaction time of peroneus brevis, fast concentric strength of plantar flexor muscles, slow eccentric strength for inversion, and passive inversion joint position sense (48), poor postural stability (49,50), impaired proprioception (51), and higher plantar flexors/dorsiflexors and evertors/invertors strength ratios (52), and inadequate or improper rehabilitation. Extrinsic risk factors comprise specific sports or activities at risk, competition level, type of shoe, playground, ankle taping and bracing (52–54).

2.2.1.1.C. Sign and Symptoms

The sign and symptoms of the acute sprain injury typically is swelling, tenderness, ecchymosis, pain over the lateral side of ankle and difficulty with movement and full weight-bearing (25,43). The initial inflammatory response causes scar formation predisposed to inadequate function with a 60% decrease in energy absorbing capacity relative to uninjured natural tissue (55). Depending on the severity of the sprain, the function generally returns from a few days to several months (25).

2.2.1.1.D. Assessments

The mechanism of injury, previous injury history, observation, and palpation give significant information about the anatomical structures which may be injured after an acute ankle sprain. The assessment of active, passive, and resistive ROM of the ankle also gives an insight into the damage arising from ligaments, tendons, muscles, and nerves (56).

The clinical evaluation consists of anterior drawer sign and inversion talar tilt tests. Increased anterior drawer movement implies elongation or rupture of the ATFL. Increased inversion compared with the healthy contralateral ankle indicates elongation or rupture of the CFL or more commonly, a combination of ATFL and CFL ruptures (41). The anterior drawer and inversion talar tilt tests are more accurate at the fifth days following the injury than second days (56). In addition, the combination of anterior drawer test, localized tenderness, and hematoma assessments has 96% sensitive and 84% specific (21).

The Ottawa Ankle Rules (OARs) have validity for the clinical instrument to determine the necessity for acute ankle injury or midfoot radiographs. Stress radiography is an unreliable instrument to find disruption of acute ligamentous after an acute ankle sprain (56). After an acute injury, Magnetic resonance imaging (MRI) is a valid and reliable technique to find out tears of the ATFL and CFL. Diagnostic ultrasound is also used for detecting the damage but less accurate and sensitive in comparison to MRI. Arthrography and tenography have less diagnostic accuracy compared to MRI and CT, especially in 48 hours following lateral ligamentous injury (41,56).

2.2.1.1.E. Classification

Lateral ankle ligament injuries are classified Grade I to III, based upon the level of ligamentous damage and morbidity. Table 2.1 demonstrates the 3 grades of an acute ankle sprain. Grade I sprain represents mild injury with the stretched ATFL and a portion of some of the ligament fibers tear. However, clear ligamentous disruption is not seen. Clinically, the patient indicates mild swelling, no or little hematoma, point tenderness on the ATFL, no laxity and no or slight restriction of active ROM. Sometimes, even full weight-bearing may be difficult (3,28,41).

Grade II sprain represents moderate injury of the lateral ligamentous structures, commonly with a complete rupture of the ATFL and an accompanying partial tear of the CFL. Assessment demonstrates active ROM restricted by localized swelling, hemorrhage, ecchymosis, and tenderness on the anterolateral side of the ankle. Abnormal lateral ligament laxity may be mild or absent. In addition, patients experience loss of functionality in term of the capability to toe rise or jump on the injured side. In the acute situation, a grade II sprain accompanied by swelling and loss of function makes it indistinguishable from a grade III sprain (3,28,41).

Grade III sprain involves complete rupture of the ATFL and CFL, probably with the capsular tear. An additional partial tear of the PTFL may be present. The evaluation often shows diffuse swelling, ecchymosis on the lateral aspect of the ankle and heel, and tenderness on the ATFL, CFL, and anterolateral capsule. The anterior drawer or inversion tests usually demonstrate moderate to severe laxity in the injured ankle.

However, it may not be elicited during the examination due to the amount of swelling and muscle spasm (3,28,41).

Table 2.1. Classification of acute ankle sprain according to its grade, severity, pathophysiology and clinical findings

Grade	Severity	Pathophysiology	Clinical findings
Grade 1	Mild	Stretch of the ATFL, causing tear of the ligament fibers.	Mild swelling, little hemorrhage, no laxity, tenderness on the ATFL and difficulty in full weight-bearing.
Grade 2	Moderate	Moderate injury to the lateral ligamentous complex with a complete tear of the ATFL ± Partial tear of the CFL.	Localized swelling, hemorrhage ecchymosis, and tenderness on the anterolateral aspect. Abnormal laxity may be mild or absent.
Grade 3	Severe	Complete disruption of the ATFL in company with CFL and PTFL.	Diffuse swelling, ecchymosis on the lateral ankle and heel, laxity, tenderness on the ATFL, CFL and anterolateral capsule.

2.2.1.1.F. Treatments

Treatment after acute ankle injury includes protection, rest, elevation, ice and immobilization (PRICE) for a short period (39,43,57–60). The treatment strategies for the reduction of pain and edema, and functional improvement involve early mobilization and non-steroidal anti-inflammatory drugs with strong evidence, exercise and manual therapy techniques with moderate evidence. Exercise-based rehabilitation and bracing help in the prevention of CAI (7,61). Protection from inversion is required at this stage of healing to prevent overgrowth of the weaker type III collagen which may cause permanent elongation of the ligament. The collagen tissue begins to mature at about 3 weeks following the injury. At this phase, proper collagen fiber orientation is promoted by controlled stress on the ligament. Also, stretching and strengthening of the ankle prevent the detrimental consequences of immobilization on the bone, joint, and muscle. While the ligament shows healing, the collagen matrix continues to mature. Therefore, full return to sports or activities may be possible at 4 to 8 weeks after the injury. Proprioceptive training is usually initiated as soon as possible after 3 to 4 weeks. The aim of proprioceptive exercise training is to enhance the balance and NMC of the ankle thereby preventing recurrent ankle sprains (28,39,43,57–60).

In systematic review articles, using the supervised physiotherapy has been shown to provide limited or moderate benefits in returning to sports or work more quickly than in a home-based rehabilitation program. Additionally, in the later phases of the rehabilitation, proprioceptive or neuromuscular exercises have the effect that can prevent the recurrence of ankle ligament injuries and generally reduce risk of recurrent ankle sprains by 35% (43). Neuromuscular rehabilitation is known to have a short term effect, but long term follow-up results are unknown. Patients who do not show improvement with conservative treatment may benefit from surgical intervention (39,43,57–60).

2.3. Chronic Ankle Instability

Repetitive ankle sprains and persistent symptoms are defined as chronic ankle instability (CAI) seen in 10-30% of individuals who suffer from acute LAS. Chronic ankle instability has been defined as either mechanical instability related to anatomical abnormalities of the ankle or functional instability related to posture disorders or tendon and muscle adaptation (29,62).

2.3.1. Pathomechanics

The mechanism of the recurrent ankle instability is not considered to be different from the first acute ankle sprains; however, it is believed that adverse changes after initial injury make individuals predispose to recurrent sprains. The cause of CAI has characteristically considered as mechanical instability and functional instability. The full spectrum of abnormal situations associated with CAI is not sufficiently described by these two terms. Clarifying the potential inadequacies that cause each instability makes it easy to identify all of the possible causes of the CAI. Mechanical and functional instability are possibly not mutually exclusive. However, these intabilities are more likely to make a continuous pathological contribution to the CAI (Figure 1.14) (25).

2.3.1.1. Mechanical Instability

Mechanical instability of the ankle eventuates in consequence of anatomical changes leading to inadequacies that make the ankle more prone to instability after the first ankle sprain. These alterations involve pathological laxity, arthrokinematics impairments, synovial and degenerative changes that may occur in isolation or combination (25,29).

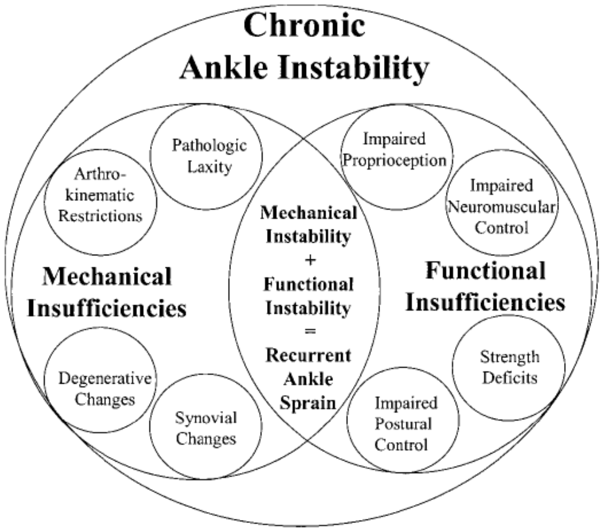


Figure 1.14 Schema of mechanical and functional inadequacies that lead to chronic ankle instability (25).

2.3.1.1.A. Pathological Laxity

Pathological laxity of injured joints may be due to the ligamentous damage of the ATFL, CFL, and deltoid after injuries, thus causing mechanical instability for injured joints. The degree of pathological laxity of the ankle is associated with the degree of damage in the lateral ankle ligaments. Pathological laxity may cause ankle joint instability in positions which may result in ensuing injury to the structures during sports or functional activities. The clinical assessment of pathological laxity may be physical examination, instrumented arthrometry, or stress radiography. Pathological laxity is commonly seen in the talocrural and subtalar joints after LAS (25).

2.3.1.1.B. Arthrokinematic Impairments

Arthrokinematic impairments at any of ankle joints are another potential insufficiency which contributes to mechanical instability of the ankle. A restricted arthrokinematic motion due to recurrent ankle sprains may cause a fault in the position of the inferior tibiofibular joint. The distal fibula displaced anteriorly and inferiorly may be seen by individuals with CAI. Restricted motion of the lateral malleolus in this displaced position may cause the ATFL to become more slack in the resting position. In this way, while the rearfoot supinates, the talus may pass through a greater ROM before the ATFL is stretched. This malposition of the fibula may cause recurrent ankle instability (25).

Hypomobility or reduced ROM, may also be considered as a mechanical inadequacy. Limited dorsiflexion ROM is considered as a predisposing factor for LAS (63). If the talocrural joint does not reach full dorsiflexion, the joint cannot reach the close-packed position during stance and so, inversion and internal rotation can be produced more easily. Also, in the closed kinetic chain, restricted dorsiflexion is usually compensated with increased subtalar pronation. Several research findings show that athletes who suffered from repetitive ankle sprains have restricted dorsiflexion (25,64).

2.3.1.1.C. Synovial and Degenerative Changes

Insuffiencies caused by synovial hypertrophy or the degenerative changes in the ankle joint may also give rise to mechanical instability of the ankle. Synovitis which is inflammation of synovial membrane is usually seen in the talocrural and posterior subtalar joint capsules. Individuals with synovitis mostly experience recurrent bouts of ankle instability and pain caused by impingement of synovial hypertrophic tissue between the relevant ankle bones (25). Also, chronic ankle instability has been associated with degenerative joint lesions in the ankle (65).

2.3.1.2. Functional Instability

Functional instability (FI) resulting from proprioceptive and neuromuscular deficits is hypothesized to be a main factor contributing to CAI. Freeman et al who first defined the concept of FI correlated impaired balance with damage of joint mechanoreceptors in the ankle resulting in proprioception deficits after LAS (66,67). Although impaired proprioception contributes significantly to FI, it is unclear why ligamentous injuries show a predisposing effect on functional ankle instability. The presence of impaired proprioception and cutaneous sensation, slowed nerve conduction velocity and delayed neuromuscular reactivity, defect in balance and muscular strength have demonstrated functional inadequacies in individuals with acute LAS or CAI (25,29).

2.3.1.2.A. Impaired Proprioception and Sensation

Proprioception is a complex of sensations that consciously and unconsciously include senses of joint position, joint movement, muscle tension or force, and effort (29,68). Impairment of ankle proprioception is likely to occur in individuals predisposed to recurrent ankle sprains, as seen in measurements of kinesthetic sense and joint position sense (69). Most researches demonstrate that proprioception in participants with CAI is impaired by reduced joint position sense (70). Recent evidence indicates that proprioceptive deficits in the ankle may be more affected by the change in the activity of muscle spindle in the peroneal muscles than altered joint mechanoreceptor activity (71).

After an acute LAS, deficits in cutaneous sensation and nerve-conduction velocity are considered as a sign of common peroneal nerve palsy. However, no evidence has been found that these impairments existed in individuals with CAI (25).

2.3.1.2.B Impaired Neuromuscular-Recruitment Patterns

Impaired neuromuscular-firing strategies have been reported among individuals with CAI. This has been most frequently demonstrated by evaluating the reflexive peroneal muscle reaction time to inversion perturbations. Contradictory consequences in literature may result from methodological differences between researchers (72). Impaired peroneal muscle reaction may be because of impairment in proprioception, neuromuscular-firing patterns, or slow nerve conduction velocity. Recent research evidence demonstrates bilateral impairments of gluteus medius muscle recruitment in participants who have suffered from a severe unilateral ankle sprain (73). Therefore, neuromuscular impairments exist not only in injured ankle structures but also through the neuromuscular pathways in the uninjured side, thus demonstrating central neural adaptations of peripheral joints (25).

2.3.1.2.C. Impaired Postural Control

Balance deficit during single-legged stance is observed in individuals suffering from an acute ankle sprain (66,67,74) or with a history of recurrent ankle instability (49,75). Even though conflicting findings are present, impaired postural control has been reliably shown between stable and unstable ankles using instrumental evaluation despite varying methods (49,76).

Impaired postural control is likely as a result of a combination of deficits in proprioception and neuromuscular control (NMC) that comprises the subconscious processing of sensory information in the central nervous system (CNS) and the control of muscle movement throughout coordinated muscle activity (13). The role of NMC is to facilitate and maintain postural control and functional joint stability by providing dynamic restraints during joint motion and loading (14). Any injury causing the damage of the mechanoreceptors, changes in normal sensory input and impedes of the processing of sensory information may cause altered NMC and consequently, result in injury or dysfunction in postural control and dynamic joint stability and also functional ankle instability (13–15). Even if healing is observed after injury, the function of mechanoreceptors may not be recovered, causing NMC deficits that may cause CAI. Also, the level of damage to the receptors and alterations in CNS processing may contribute to CAI. A systemic review has presented strong evidence that the balance has bilaterally impaired following acute LAS (77). Some reports have also suggested that after acute LAS, bilateral postural control deficits occur with suggesting central changes or impairments in NMC (16,78). Thus, NMC is not only affected by peripheral mechanoreceptors damage, but also adaptations in the central pathways may partly cause deficits after an ankle sprain (25). Also, it has been considered that the neural mechanism like spinal reflexes or interaction between the cerebral hemispheres might mediate bilateral impairments (79).

While maintaining balance in single-legged stance, the foot performs pronation and supination movements in an effort to maintain the center of gravity of the body above the base of support. This situation is called as the ‘‘ankle strategy’’. However, individuals with CAI usually tend to perform ‘‘hip strategy’’ which is less effective than the ankle strategy, in order to keep unilateral balance compared to uninjured individuals. The change in the strategy of postural control may be due to alterations in CNS in the existence of ankle joint dysfunction (25).

2.3.1.2.D. Strength Deficits

Muscle strength deficits, especially in evertor muscles, have been reported among individuals with CAI. Several studies have reported that also decreased invertor muscles strength. On the contrary, some studies in the literature have demonstrated that no strength deficits present in patients with CAI (25,70,76,80).

2.3.2. Treatment and Prevention

The natural progress of acute ankle sprains is that individuals gradually recover in the weeks following injury in terms of pain, swelling, and loss of function which are the initial symptoms of sprains. Overall rehabilitation plans emphasizing balance, proprioceptive, and neuromuscular control exercise training, strengthening of peroneal muscles considerably decrease the risk of repetitive ankle sprains (20). Also, ankle taping and bracing is an effective method to prevent recurrent ankle instability. However, these methods alone are unlikely to be as effective as an overall rehabilitation plan combining with ankle taping or bracing.

Preventive methods to decrease the frequency of repetitive ankle sprain cases should address pathological laxity, arthrokinematic alterations associated with mechanical instability and the impairments in proprioception and neuromuscular related to functional instability (25).

2.3.2.1. Exercise Training

According to the Cochrane review (2011), neuromuscular training provides short-term improvement for CAI-related symptoms (6). Recent research demonstrated that the ankle positions of athletes with CAI were relatively inversion and that the ankle orientation changed toward minimally an everted direction after 6 weeks of neuromuscular training (17). Cruz-Diaz et al. claimed that balance training exercises based on multi-station tasks significantly improved self-reported sensation of instability and dynamic balance in individuals with CAI (18). O'Driscoll et al. also indicated that the 6 weeks of dynamic neuromuscular exercise training led to improvements in ankle sensorimotor control of athletes with CAI (19). According to a systemic review, proprioceptive training programs are found to be effective in decreasing the incidence of ankle sprains in sports participants, particularly individuals with history of ankle sprains. Hop stabilization training for 6 weeks was found to be effective in improving self-reported function and neuromuscular control among college basketball players with CAI (81). Some studies have observed the positive effects of balance exercise training program for 4 weeks on static and dynamic balance, and also lower extremity function of individuals with CAI (82–85). In a study comparing balance and strength protocols, it was observed that both protocols increased strength, balance, and function (86). Some researches also demonstrated that the neuromuscular rehabilitation program is immediately effective in improving postural control and gaining eccentric evertor muscle strength, and in the long term, it was found to contribute to increasing evertor strength of unstable ankles. On the other hand, improved postural stability was found to be non-permanent (87). Present evidence remains inadequate in the benefits of primary prevention of ankle sprains (88).

2.3.2.1.A. Cross-Education

Cross-education phenomenon was firstly described as by Scripture et al. It is also called muscular crossed effect (89). Some studies have demonstrated that cross-education occurs in neurologically healthy individuals following high-intensity unilateral resistance exercise training for short-term (ie 4-6 weeks). It is frequently claimed that unilateral strength training of any extremity increases the strength of the contralateral homologous muscle group. Increased contralateral strength accounts for approximately 7-8% after 6-week training (90–92). Even though no consensus has been reached on the cross-education mechanism that induces contralateral strength adaptations, it has been proposed that the strength improved on the untrained side is associated with increased strength on the trained side. The contralateral effect of unilateral training has been thought to be due to increased voluntary activation through increased motor unit firing rates and recruitment via CNS mechanisms (91).

Voluntary movements in the unilateral limb have been demonstrated to produce contralateral effects at the cortical region and activate the ipsilateral and contralateral sensorimotor cortex (93,94). This is thought to create a learning effect for muscle activation of the untrained limb after unilateral training of one limb (94). Furthermore, it is believed that there are neural alterations at also spinal and supraspinal levels (90,93,95). Although it is not yet clear where the neural adaptations occur and how spinal and supraspinal mechanisms have effects on cross-education, spinal and supraspinal contributions have been observed in the trained leg, but only the supraspinal mechanism has been contributed to the untrained leg (96,97).

Regarding supraspinal factors, authorities assert that contralateral primary motor cortex operates unilateral motor commands and activities. Kristeva et al. (98) have claimed that excitation of ipsilateral motor cortex during a voluntary muscle contraction may affect the contralateral motor cortex. Also, it has been suggested that approximately 15% of corticospinal fibers cross over to the contralateral lobes and that the coactivation of homologous muscles results from descending motor signals from the ipsilateral motor cortex (97).

Bilateral improvement in a contralateral limb is not only seen in muscular strength but also balance and neuromuscular control. Hale et al. (15) claimed that positive improvements in dynamic balance and lower extremity function may be seen on the unstable ankle side after 4-weeks of balance exercise training for the stable ankle. In addition, some researchers observed bilateral improvements in NMC following CAI rehabilitation (15).

The exercise training for only the stable ankle in individuals with CAI may lead to postural control improvements on the unstable ankle when considering the bilateral deficits following the unilateral injury. Therefore, clinicians are likely able to early begin neuromuscular training including the stable ankle rehabilitation as a part of the comprehensive rehabilitation strategy for individuals or athletes with CAI to avoid losing time, lower extremity functions and sports performances. Many athletes return to sports within 15 days even with many reporting pain and deficits in function and postural control after an acute LAS (16). Researchers (20) also suggested that neuromuscular training should be started after the pain and weight-bearing restrictions are removed. Thus, the time spent to restore postural stability before returning to sports is minimal, possibly resulting in increased risk for re-injury and residual dysfunction among athletes. By starting NMC training earlier, it is possible for athletes to return to sports without loss of function and ready for the functional requirements of the sport. Therefore, the aim of our study was to investigate the effects of unilateral balance exercise training program for 4 weeks on bilateral balance and explosive power among athletes with CAI. In this study, unilateral balance exercise training program including balance and hop-stabilization exercises for stable or unstable ankle was used to determine its effects on balance and sports performance in athletes with CAI.

3. MATERIAL AND METHOD

3.1. Subjects

The sample of the study consists of athletes with chronic ankle instability (CAI) at least 6 months and in team sports including either basketball, volleyball or handball at Yeditepe University Culture and Sports Directorate.

The study included 28 athletes (15F, 13M) with CAI. The athletes with CAI who met inclusion criteria are divided into three groups. The randomization for groups was conducted by using statistical computing web programming (99). Athletes in first group are involved in the rehabilitation group for the stable ankle (SG) and athletes in second group were included in the rehabilitation group for the unstable ankle (UG). The control group (CG) was involved in our study to eliminate the bias and learning effects of the tests which would be applied.

3.1.1. Inclusion Criteria

The athletes who fulfilled the following inclusion criteria according to the International Ankle Consortium for CAI were recruited to the experimental groups (100).

- Participating in the study on a voluntary basis
- Athletes with 18-25 years old
- Being a player in one of the basketball, volleyball, and handball team sports
- Athletes with a history of at least 2 significant LAS which was classified as a second degree and related to inflammatory symptoms (pain, swelling)
- The self-reported sensation of giving away and instability at the injured ankle confirmed by the Cumberland Ankle Instability Tool (CAIT) with a score ≤25 (101)
- Recurrent LAS episodes of the injured ankle occurred at least 12 months
- The self-reported function of the injured ankle confirmed by Foot and Ankle Ability Measure with a score <90% from activities of daily living subscale and <80% from sport subscale.

3.1.2. Exclusion Criteria

The athletes who fulfilled the following inclusion criteria according to the International Ankle Consortium for CAI were not recruited to the experimental groups (100).

- A history of surgery to the musculoskeletal structures in either lower extremity
- A history of a fracture in either lower extremity necessitating realignment
- Acute injury of musculoskeletal structures of other joints of the lower extremity in the previous 3 months affecting joint function and integrity
- Presence of bilateral ankle instability
- Balance or vestibular disorder (15)

The purpose and plan of the study were explained to the participants. All participants were involved in the study on a voluntary basis and informed written consent was obtained from each. (Appendix 1). The study protocol was approved by the Yeditepe University Ethical Committee at the date of 14.02.2019 and issue number was 37068608-6100-15-1609 (Appendix 2).

3.1.3. Flow of Research

We planned to have 32 athletes with CAI for three groups. As for the first step, we separated the participants according to the statistical computing web programming (99). Athletes in the first group were included in rehabilitation group for the stable ankle (SG) and the athletes in second group were included in rehabilitation group for the unstable ankle (UG). Athletes in third group were included to control group (CG).

After the end of the first assessment, 4 weeks exercise training program initiated with two groups of participants. However, three athletes who did not attend the training program regularly were excluded from the study. One athlete who had Grade 2 acute ankle sprain in team training was excluded from the study. No participant withdrew from the study due to adverse effects of the training program (Figure 3.1 Flowchart Diagram).

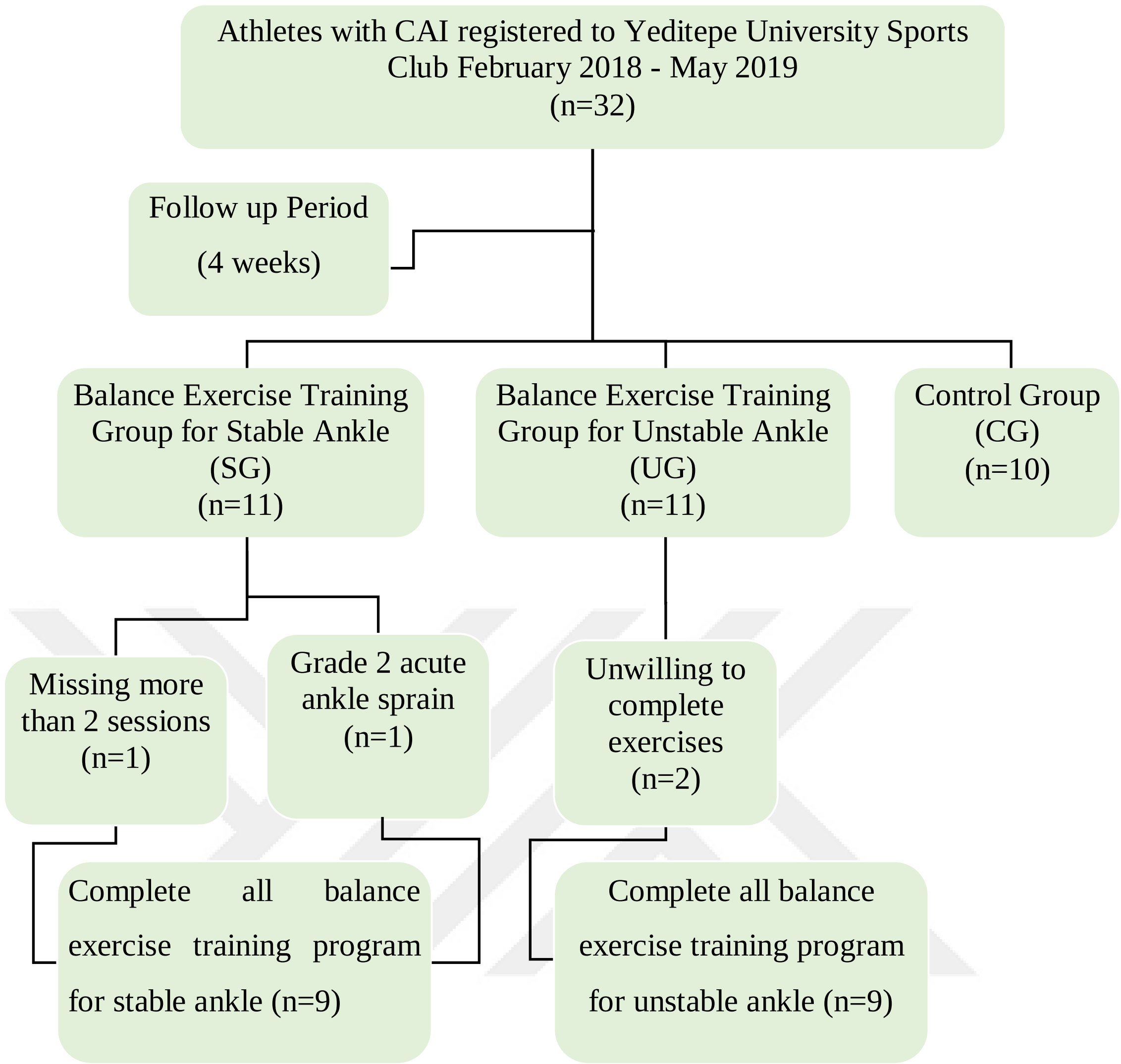


Figure 3.1 Flowchart Diagram

3.1.4. Study Protocol

The 4-week exercise training program including balance and hop stabilization exercises for the athletes with CAI in the SG and UG was conducted by the physiotherapist. Stable or unstable ankle, which satisfied the inclusion criteria, were trained with determined balance exercise training protocol according to groups. However, both ankles in all groups were analyzed by static and dynamic balance tests, and sports performance tests. The control group comprised of 10 athletes with CAI. Measurements and alterations in static and dynamic balance tests and sports performance tests were measured at baseline and 4th week of exercise training. The rehabilitation groups participated in the exercise training protocol twice a week for 4 weeks, while the control group was instructed to resume activities of daily living and sports. Each training session took approximately 30 minutes. The exercise training protocol included supervised, balance and hop stabilization exercises focused on the recovery of static and dynamic balance and improving explosive power (Table 3.1). The exercise program was designed based on evidence-based exercises that reported in similar clinical trials in the literature (75,83,85,102,103). The exercise program of each athletes was advanced depending on their performance through the exercise sessions. We developed specific criteria for progress to ensure consistency among participants (Table 3.1.). During the training session, participants completed the exercises for only the stable or the unstable ankle according to rehabilitation groups (16).

3.2. Evaluation

3.2.1. Structured Questionnaire for Patient's Demographic Characteristics

The structured questionnaire prepared the researchers and to be applied face to face; includes questions about the age, gender, educational level, socio-demographic conditions, existing chronic diseases, surgical conditions, injuries and type of sport, performance level, training frequency (Appendix 3).

3.2.2. Cumberland Ankle Instability Tool (CAIT)

CAIT including a 30-point scale of 9-items is a valid and reliable questionnaire for distinguishing and quantifying the severity of functional instability. Clinically, CAIT is an effective tool for evaluating the severity of FI, monitoring progress and measuring treatment outcome. In researches, the CAIT provides the identification, objectively definition and comparison of more homogenous subject groups. Participants with a score of 25 or higher are less likely to have functional instability, while those with a score of 25 or lower are more likely to have functional instability (Appendix 4) (104).

3.2.3. Foot and Ankle Ability Measurement (FAAM)

Physical functions of athletes were assessed by Turkish version of Foot and Ankle Ability Measure (FAAM) (105). The FAAM is a self-reported tool improved to evaluate the physical functions of individuals with musculoskeletal disorders related to foot and ankle. The FAAM is a 29-item questionnaire including 21-item Activities of Daily Living (ADL) and 8-item Sports subscales. The Sports subscale evaluates the ability to perform sports-related activities, a sub-class of population-specific for athletes. Each answer options is scored on a 5-point Likert scale which ranges from 0 to

4 and represents different levels of difficulty. The maximum score is 84 points for the ADL subscale and 32 points for the Sports subscale. Total score are calculated as percentage scores ranging from 0% to 100%. A higher score corresponds to a higher level of function for both subscales. Participants also scored their level of function from 0% (inability to perform daily and sports activities) to 100% (functional level before the injury). The Turkish version of FAAM was found to be valid and reliable for the self-reported physical function among Turkish-speaking individuals with CAI (ICC = 0.97 for FAAM-ADL and 0.94 for the FAAM-S subscales (Appendix 5) (105–108).

3.2.4. Balance Error Scoring System (BESS)

Static balance deficits of the athletes with CAI was assessed by using the BESS. The BESS includes double-legged stance, single-legged stance, and tandem stance conditions on both firm and foam surfaces with eyes closed (Figure 3.2, 3.3). The test was applied twice to compare differences between pre and posttest results for both stable and unstable ankle. Firstly, the participants stood on both ankles on both firm and foam surfaces during the double-legged stance condition. Secondly, they stood on the stable ankle during the single-legged stance, and then stood on the unstable ankle in the front and the stable ankle in the back on both firm and foam surfaces during the tandem stance. These conditions were repeated on both firm and foam surfaces for the unstable ankle. A stopwatch was used for timing the participants during 20-second trials. Before testing, the participant was instructed to remove their shoes and any taping or brace on their ankle and informed about the protocol. Each trial was scored by counting the errors on the BESS score card performed by the athletes (Appendix 6). The maximum total number of errors for any condition was taken as 10. The BESS has been presented to be a valid test to find out deficits in static postural control of individuals with CAI and also demonstrated to have interrater reliability which ranges from 0.78 to 0.96 (109,110).

a. Double - Legged Stance b. Single - Legged Stance c. Tandem Stance

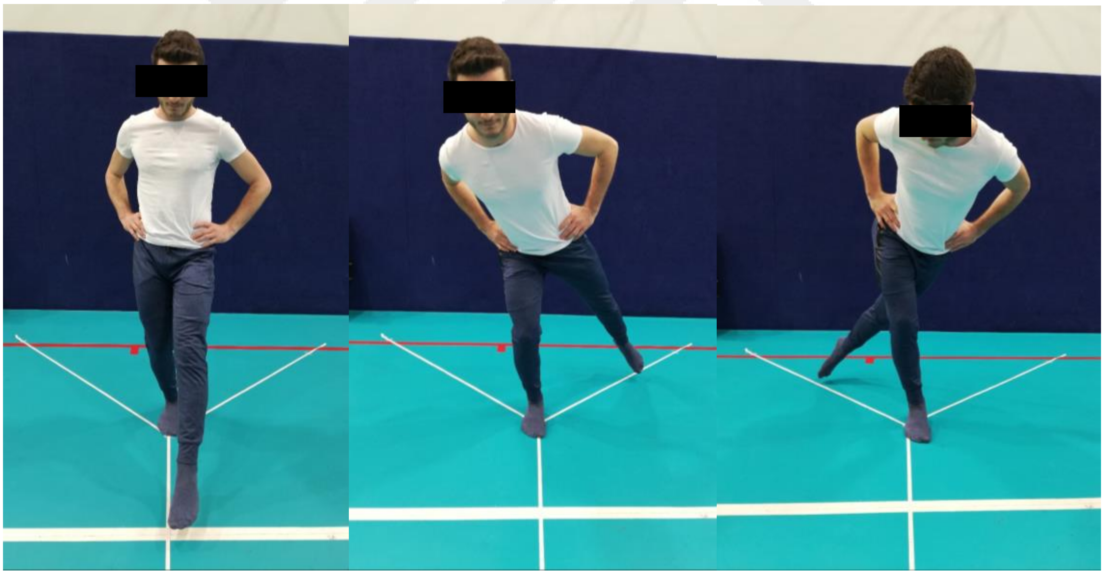
Figure 3.2 Balance Error Scoring System – Firm Surface (a, b, c)

a. Double - Legged Stance b. Single - Legged Stance c. Tandem Stance

Figure 3.3 Balance Error Scoring System – Foam Surface (a, b, c)

3.2.5. Dynamic Balance Assessment - Y Balance Test

Dynamic balance of the athletes was evaluated by using the Y Balance Test which is improved to modify Star Excursion Balance Test (SEBT). SEBT is a more functional test that is able to find out impairements in dynamic postural control among individuals with CAI. It is reported to have high intratester reliability (0.82–0.96) and intertester (0.81–0.93). The Y Balance Test includes 3 different positions where the individual stands first on the stable ankle and then on the unstable ankle, with the hands-on the hips, maintained a single-legged stance while reaching as far as possible with the contralateral limb in the anterior direction, posteromedial direction, and posterolateral direction (Figure 3.4). The test apparatus was pulled with three tape measures in these 3 directions between 90° and 135°. In order to eliminate the learning effect, subjects were allowed to reach each direction 3 times before beginning the test. Athletes were requested to reach as far as they could reach without disturbing their balance. Then, the examiner noted the point they reached in cm. The test was repeated 3 times in all directions. Athletes were given 15 seconds to rest between each direction trial. The average of three repetitions reached was recorded for all three directions. Normalized reach distances for all directions were calculated by dividing the average of three repetitions to lower limb length of the athletes measured from the spina iliaca anterior superior to the distal apex of the medial malleolus and by multiplying with 100. (Appendix 7) (111,112).



a. Anterior b. Posteromedial c. Posterolateral

Figure 3.4 Y Balance Test (a, b, c)

3.2.6. Lower Extremity Power Assessment

3.2.6.1. Vertical Jump Assessment

The Single Legged-Countermovement jump (CMJ) test was used to evaluate the lower-extremity power of athletes, and indirectly the functional performance. The athlete was instructed first to jump on the uninjured leg and then on the injured leg to the highest vertical distance 3 times. The average of 3 repetitions reached was recorded. The distance between the distance that lies before the jump and the highest distance that it could reach by jumping was measured in cm (Figure 3.5, 3.6) (Appendix 7).

Figure 3.5 The distance before jump

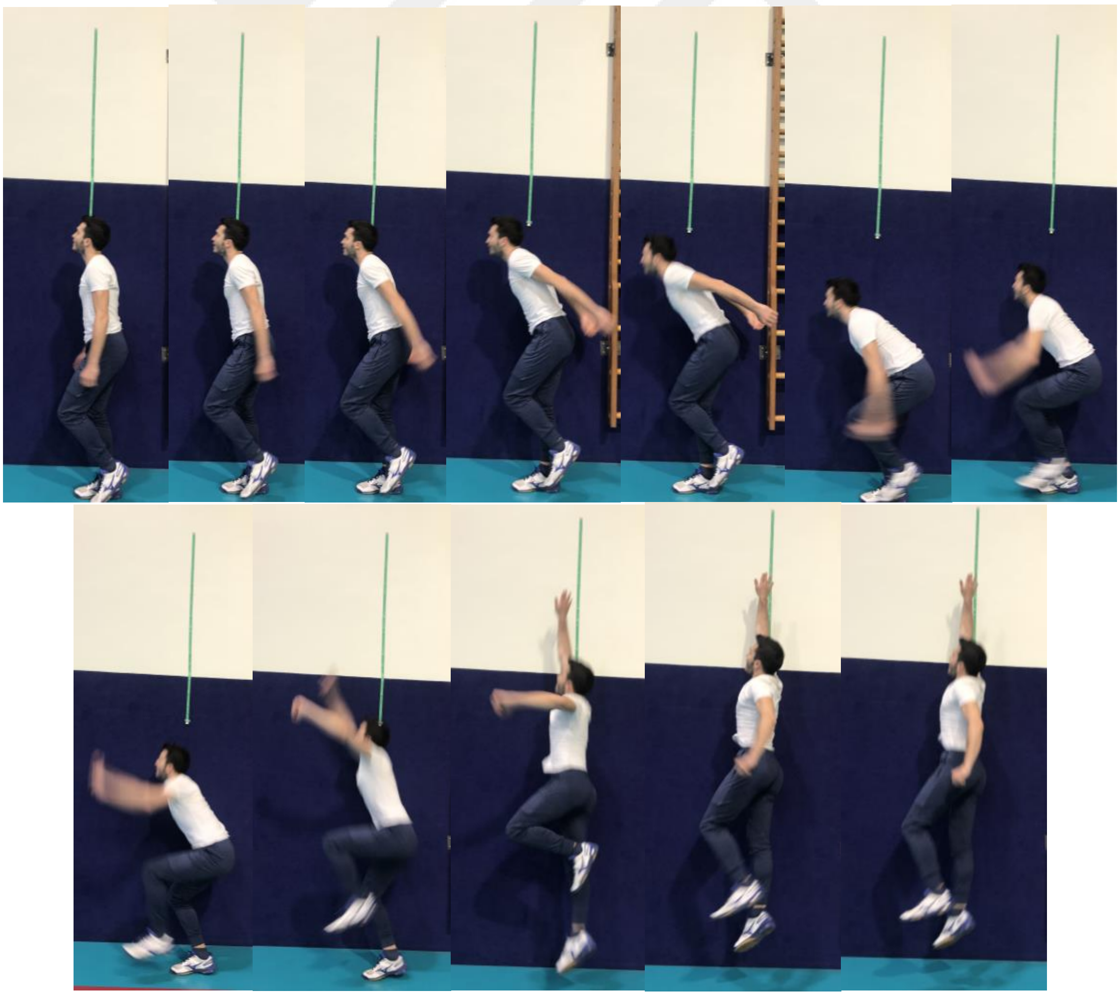


Figure 3.6 Single-Legged Countermovement Jump Test

3.2.6.2. Figure-of-8 Hop Test

Figure-of-8 Hop Test was used to measure the explosive power of the lower extremity of athletes. For this test, an area of 5 m confined by cones is used. The athlete was instructed first to complete the action on the uninjured leg and then on the injured leg 3 times with the fastest way. The average of 3 repetitions completed was recorded. The completion time of the test was measured in seconds (Figure 3.7) (Appendix 7) (113).

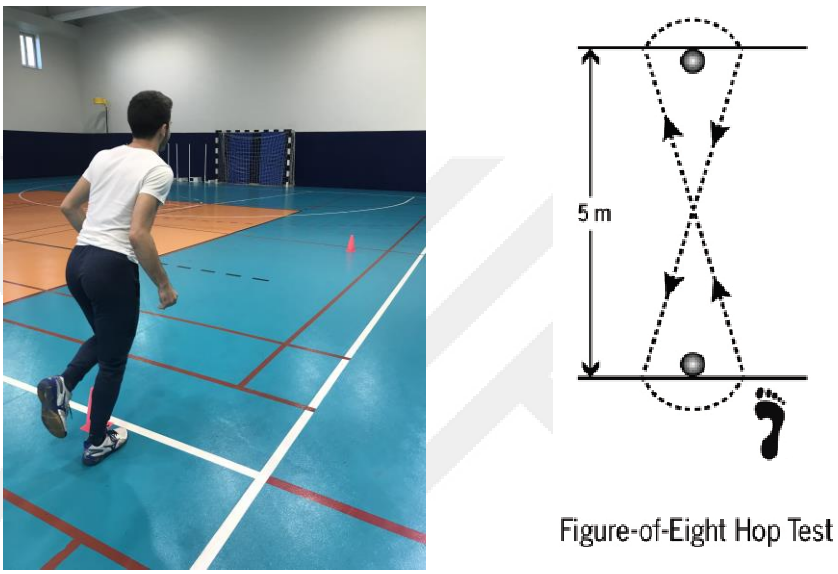


Figure 3.7 Figure-of-8 Test

3.2.6.3. Side Hop Test

Side Hop test is another test used to evaluate the explosive power of the lower extremity of athletes. All athletes were instructed to hop laterally with stable and unstable ankles over a distance of 30 cm. One repetition was counted as a lateral hopping over the 30 cm and hopping back to the initial position. Each athlete was instructed to complete 10 repetitions and make it as quickly as possible. The completion time of the test was measured in seconds. The test was repeated 3 times. The average of 3 repetitions was recorded (Figure 3.8) (Appendix 7) (113).

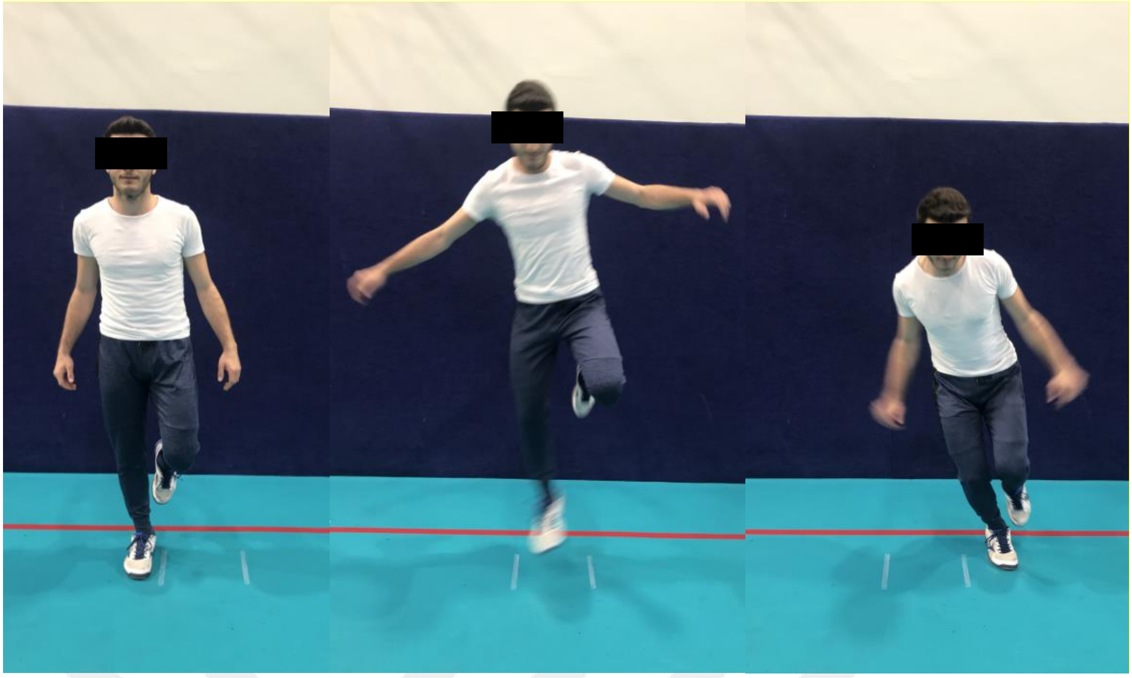


Figure 3.8 Side Hop Test

3.3. Intervention

There were 7 exercises including balance and hop stabilization exercises for athletes with CAI. Both experimental groups were able to develop the exercise program in accordance with the progression in Table 3.1. The control group had no intervention only they were included assessment tests.

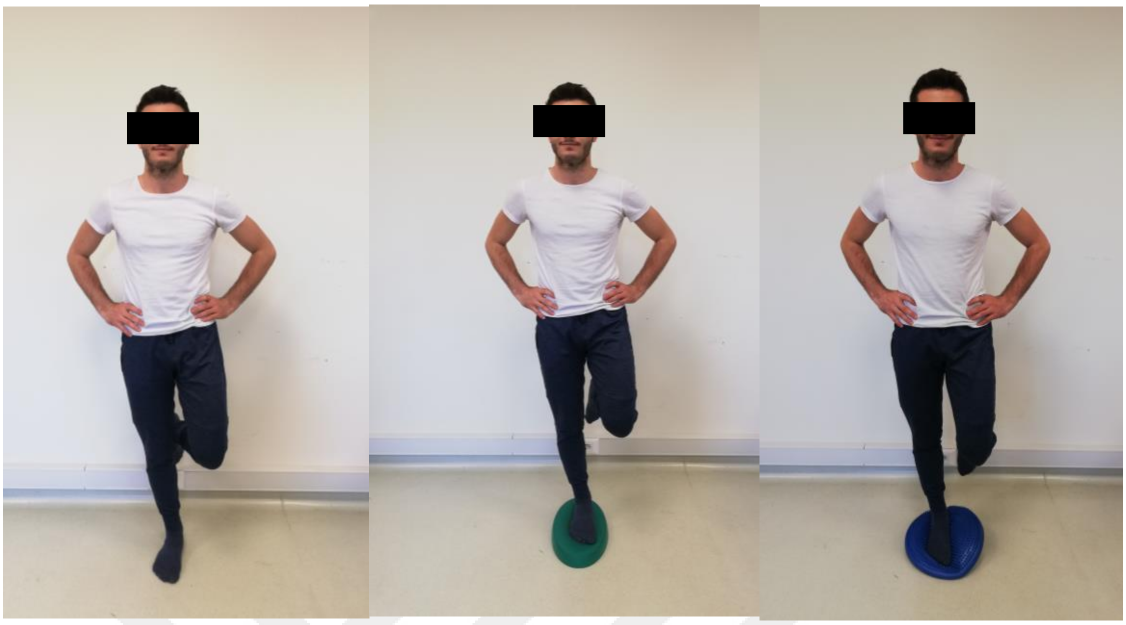
Table 3.1. Exercise Progression Program

Exercise program	Exercise Explanation
a. Single-Leg Stance (Figure 3.9)	Week 1: Performed up to 60 s per repetition for up to 3 repetitions with and without visual feedback on the firm surface
	Week 2: Performed up to 60 s per repetition for up to 3 repetitions with/out visual feedback on the soft surface using Thera-Band Stability Trainer
	Week 3-4: Performed up to 60 s per repetition for up to 3 repetitions with/out visual feedback on the soft surface using balance disc

b. Wobble Board (Figure 3.10)	Week 1: Began with using two-dimensional wobble board Slowly moved the board in the plantarflexion/dorsiflexion and inversion/eversion directions without contact the floor
	Week 2: Slowly moved the board using multi-dimensional wobble board with upper extremity support
	Week 3-4: Slowly moved the board using multi-dimensional wobble board without upper extremity support Added rotational directions
c. Steamboats (Figure 3.11)	Week 1: Tied a 120 cm Thera-Band around the unstable ankle Positioned stance foot 70 cm from where Thera band was tied on the firm surface Performed up to 3 sets of 15 repetitions in each direction (hip flexion, extension, adduction, abduction)
	Week 2: Positioned stance foot on the soft surface using Thera-Band Stability Trainer Performed up to 3 sets of 15 repetitions in each direction (hip flexion, extension, adduction, abduction)
	Week 3-4: Positioned stance foot on the soft surface using balance disc
d. Single-Leg Hop	Week 1: Hopped as far as comfortable in the anterior direction. Performed up to 5 repetitions
	Week 2: Performed up to 10 repetitions adding medial, lateral and posterior directions
	Week 3: Performed up to 15 repetitions in all directions
	Week 4: Performed up to 3 sets of 10 hops
e. Single-Leg Ball Catch (Figure 3.12)	Week 1: Performed during stance on a firm surface
	Week 2: Performed during stance on a trampoline
	Week 3: Performed during stance on a balance disc
	Week 4: Performed during stance on a Bosu ball

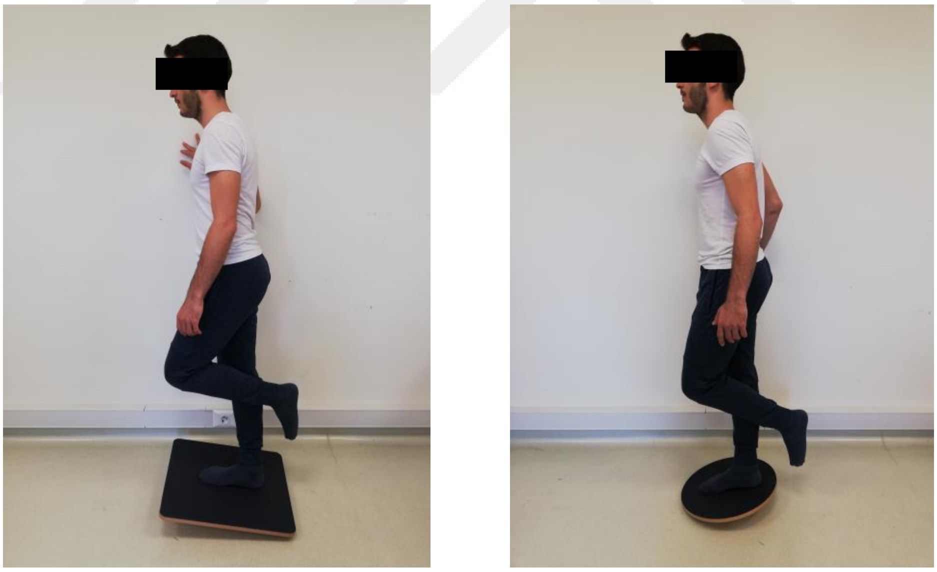
f. Quadrant Hop (Figure 3.13)	Week 2: Performed up to 3 sets of 5 hops in numbered squares clockwise and counterclockwise while maintaining the single-legged stance
	Week 3-4: Added unanticipated directional changes where investigator randomly called out numbers
g. Single-Leg Hop and Ball Catch (Figure 3.14)	Week 3-4: Performed up to 3 sets of 10 hops Positioned double-legged stance on a flat surface Hopped with one foot in the direction the ball is thrown and catches the ball Returned to starting position

3.3.1. Exercise Program



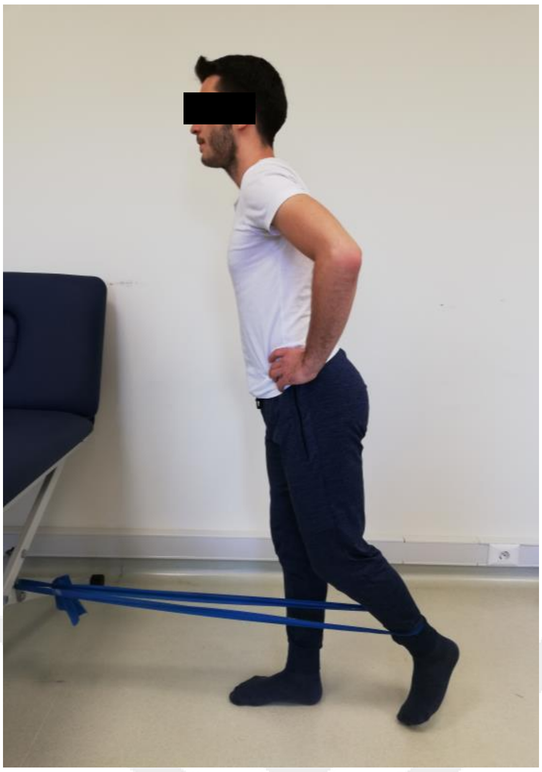
a. Week 1 b. Week 2 c. Week 3-4

Figure 3.9 Single-Leg Stance (a, b, c)



a. Week 1 b. Week 2-4

Figure 3.10 Wobble Board (a, b)



a. Week 1

b. Week 1

c. Week 2

d. Week 3-4

Figure 3.11 Steamboats (a, b, c, d)

a. Week 1

b. Week 2

c. Week 3

d. Week 4

Figure 3.12 Single-Leg Ball Catch (a, b, c, d)

Figure 3.13 Quadrant hop

Figure 3.14 Single-Leg Hop and Ball Catch

3.4. Statistical analysis

SPSS (Statistical Package for Social Sciences) version 22 was used to evaluate the data obtained from the study and to form the tables. Mean, standard deviation, median, minimum and maximum values were used for the presentation of continuous variables (quantitative variables) and frequency and percentage values were used for presentation of categorical variables (qualitative variables). Shapiro Wilk test and graphical methods were used to investigate the suitability of quantitative variables to normal distribution. The difference between the pre and post-measurements taken from athletes in groups was examined by Student’s paired sample t-test for parametric variables and Wilcoxon test for nonparametric variables. Each of the differences (delta) between these groups (SG, UG and CG) was determined by One-way ANOVA (Analysis of Variance) and Tukey’s HSD (Honestly Significant Difference) post hoc test for parametric variables, Kruskal Wallis-H test and Mann Whitney-U test for nonparametric variables. In all statistical analyses, $p < 0.05$ was accepted as the level of significance.

4. RESULTS

4.1. Descriptive Characteristics of Participants

The study included athletes with a history of CAI (n=28, 15F, 13M) registered as a team player at Yeditepe University Culture and Sports Directorate between December 2018 - May 2019. These athletes continued their team training program 90 minutes in 2 days per week during the study.

The values of mean age, weight, height, and body mass index (BMI) of the SG, UG, and CG are presented in Table 4.1. According to these findings, there was no statistical difference in three groups in terms of age and height. However, statistical difference was found in weight and BMI between SG and CG according to Tukey's HSD post hoc test.

Table 4. 1. Physical Features of Participants

	SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Age(year)	20.88 ± 2.02	21.00 ± 1.00	21.00 ± 1.49	0.01	0.985
Weight (kg)	62.00 ± 8.26	66.77 ± 12.88	78.40 ± 16.15	4.04	**0.030**
Height(m)	1.76 ± 0.07	1.74 ± 0.09	1.80 ± 0.10	1.08	0.355
BMI(kg/m^2)	19.99 ± 2.19	21.82 ± 2.06	23.87 ± 2.64	6.61	**0.005**

Data expressed as mean ± standard deviation. BMI: Body mass index. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group.

The gender, dominant hand and foot in the study groups were given Table 4.2. As a result of the statistical analysis of these values, no statistical difference was found between the three groups. The CAIT score of stable and unstable ankle side, the number of ankle sprain history and the playing time of all groups were given Table 4.3. When the values of CAIT scores, the number of ankle sprain history and playing time were examined, it was found that there was no statistical difference between the three groups.

Table 4.2. Comparison of Gender, Dominant Side of Hand and Foot among the Study Groups

		SG % (n)	UG % (n)	CG % (n)	λ²	p value
Gender	**Female**	66.7 (6)	55.6 (5)	40.0 (4)	1.37	0.503
	Male	33.3 (3)	44.4 (4)	60.0 (6)		
Dominant Hand	**Right**	77.8 (7)	88.9 (8)	80.0 (8)	0.42	0.808
	Left	22.2 (2)	11.1 (1)	20.0 (2)		
Dominant Foot	**Right**	55.6 (5)	66.7 (6)	90.0 (9)	2.90	0.234
	Left	44.4 (4)	33.3 (3)	10.0 (1)		

Data expressed as % (n). SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group.

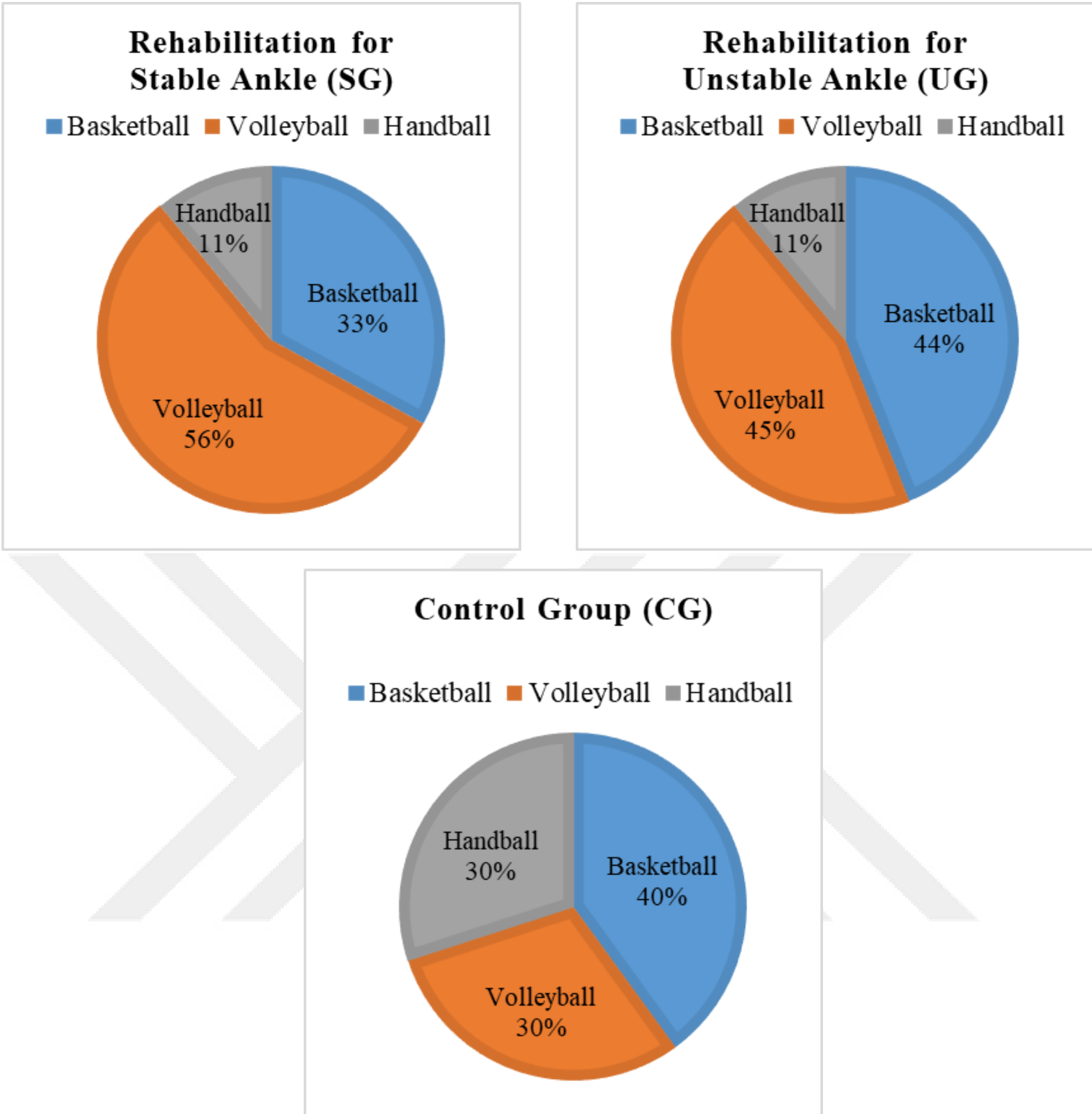
Table 4.3. Comparison of CAIT Score for Stable and Unstable Ankle Side, Number of Ankle Sprain History and Playing Time among the Study Groups

	SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
CAIT Score for Stable Side	29.33 ± 0.70	29.33 ± 0.50	29.90 ± 0.99	1.58	0.225
CAIT Score for Unstable Side	22.33 ± 2.12	19.77 ± 5.11	21.90 ± 1.59	1.73	0.198
Number of Ankle Sprain History	4.44 ± 2.65	3.77 ± 1.78	3.10 ± 0.87	1.20	0.316
Playing Time (years)	9.11 ± 3.10	10.22 ± 4.73	9.40 ± 3.02	0.22	0.803

Data expressed as mean ± standard deviation. CAIT: Cumberland Ankle Instability Tool SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group.

The distribution of sports branches among the study groups was given Graph 4.1. According to findings, there were 3 basketball, 5 volleyball and 1 handball players in SG, 4 basketball, 4 volleyball and 1 handball players in UG, 4 basketball, 3 volleyball and 3 handball players in CG (Graph 4.1.).

Graph 4.1. Distribution of Sports Branches among the Study Groups



Data expressed as %. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group.

4.2. Intergroup Comparison of Pre-Measurement Findings

The One-way ANOVA and Tukey post hoc test for parametric variables and Kruskal Wallis-H test for nonparametric variables were used to compare of variables between participants of the all groups pre and post measurements.

4.2.1 Intergroup Comparison of Pre-Measurement Findings for Foot and Ankle Ability Measure

As a result of the statistical analysis, no significant difference was found between the pre-measurements of groups in terms of values of Foot and Ankle Ability Measure (FAAM) (Table 4.4).

Table 4.4. Intergroup Comparison of Pre-Measurement Findings for Foot and Ankle Ability Measure

	SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
FAAM-ADL (%)	76.11 ± 8.57	80.00 ± 7.50	82.50 ± 5.89	3.29*	0.193
FAAM-S (%)	70.55 ± 12.10	73.33 ± 5.00	78.00 ± 4.83	2.13	0.139

Data expressed as mean ± standard deviation. FAAM: Foot and Ankle Ability Measure ADL: Activity of Daily Living S: Sports SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.2.2. Intergroup Comparison of Pre-Measurement Findings for Balance Error Scoring System

According to variables of pre-measurements, no statistical difference was found between the groups for both ankles in terms of the BESS double stance and single leg stance on both surfaces, tandem stance on the firm surface and BESS total scores (Table 4.5). In Tukey's HSD post-hoc paired comparisons, it was observed that the statistical difference in means of tandem stance-foam surface condition on stable ankle for all three groups was due to the CG. There was a significant difference between SG and CG as well as UG and CG, but no difference was found between SG and UG.

Table 4.5. Intergroup Comparison of Pre-Measurement Findings for Balance Error Scoring System

Conditions (score)			SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Double Leg Stance	**Firm**		0.00	0.00	0.00	-	-
	Foam		0.22 ± 0.44	0.66 ± 2.00	0.90 ± 1.52	3.07*	0.215
Single Leg Stance	**Firm**	**Stable**	2.88 ± 2.42	1.66 ± 1.00	2.20 ± 1.93	0.95	0.398
		Unstable	4.22 ± 2.58	3.44 ± 1.87	4.10 ± 2.33	3.30	0.740
	Foam	**Stable**	6.44 ± 1.74	6.44 ± 1.87	7.10 ± 1.72	0.43	0.652
		Unstable	8.55 ± 1.23	7.33 ± 1.58	8.60 ± 1.07	2.78	0.081
Tandem Stance	**Firm**	**Stable**	0.33 ± 0.50	0.66 ± 1.00	1.20 ± 1.68	1.27*	0.528
		Unstable	1.55 ± 1.50	2.00 ± 3.08	2.40 ± 2.31	0.84*	0.655

	Foam	Stable	2.66 ± 1.50	3.77 ± 1.85	4.80 ± 1.54	4.01	**0.031**
		Unstable	4.22 ± 1.30	4.77 ± 2.63	6.50 ± 1.90	3.33	0.052
BESS Total	Stable		12.55 ± 2.92	13.22 ± 4.46	16.20 ± 5.09	1.96	0.161
	Unstable		18.77 ± 3.89	18.22 ± 7.69	22.50 ± 5.75	1.45	0.252

Data expressed as mean ± standard deviation. BESS: Balance Error Scoring System SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.2.3. Intergroup Comparison of Pre Measurements Findings for Y Balance Test

Comparing the groups for pre-measurement findings of Y Balance Test values were showed that no statistical differences were found in the anterior, posteromedial (PM) and posterolateral (PL) direction (Table 4.6).

Table 4.6. Intergroup Comparison of Pre-Measurement Findings for Y Balance Test

Y Balance Test (cm)		SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Anterior	Stable	78.01 ± 8.17	79.83 ± 2.27	77.55 ± 6.38	5.01*	0.082
	Unstable	76.90 ± 4.69	75.95 ± 7.97	73.85 ± 6.89	0.52	0.599
Posteromedial	Stable	94.10 ± 7.26	95.28 ±10.22	95.38 ± 6.72	0.70	0.933
	Unstable	92.08 ± 9.18	91.51 ± 8.81	91.03 ± 5.91	0.04	0.961
Posterolateral	Stable	88.20 ± 8.73	91.26 ± 7.70	88.65 ± 8.20	0.36	0.696
	Unstable	86.04 ± 8.65	87.13 ± 8.80	86.87 ± 6.67	0.04	0.956

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.2.4. Intergroup Comparison of Pre-Measurement Findings for Jump and Hop Tests

According to variables of pre-measurements, no statistical difference was found between the groups for both ankles in terms of the vertical jump, figure-of-8 hop and side hop tests (Table 4.7).

Table 4.7. Intergroup Comparison of Pre-Measurement Findings for Jump and Hop Tests

		SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Vertical Jump (cm)	Stable	30.17 ± 10.23	26.46 ± 5.26	28.24 ± 8.99	0.49*	0.781
	Unstable	30.74 ± 9.67	25.50 ± 4.53	26.88 ± 9.36	1.29*	0.524
Figure-of-8 Hop (sec)	Stable	11.79 ± 1.96	11.62 ± 1.07	11.78 ± 0.76	0.04	0.954
	Unstable	12.51 ± 1.72	12.57 ± 1.54	12.41 ± 0.78	0.03	0.970
Side Hop (sec)	Stable	10.28 ± 1.85	10.15 ± 1.53	10.34 ± 1.06	0.04	0.961
	Unstable	10.81 ± 2.13	10.80 ± 1.79	10.92 ± 1.11	0.01	0.986

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.3. Intragroup Comparison of Pre and Post-Measurements Findings

A paired t-test for parametric variables and Wilcoxon test for nonparametric variables were used to examine for differences in regard to pre and posttest findings intragroup variables.

4.3.1. Intragroup Comparison of Pre and Post- Measurements Findings for Foot and Ankle Ability Measure

As a result of the statistical analysis, SG and UG demonstrated statistically significant differences between pre and posttest findings of FAAM-ADL and FAAM-S, whereas there was no statistical difference in the CG (Table 4.8). It means that the athletes in SG and UG had an improvement in results of FAAM-ADL and FAAM-S scores.

Table 4.8. Intragroup Comparison of Pre-Measurement Findings for Foot and Ankle Ability Measure

		SG Mean ± SD	Z/p	UG Mean ± SD	Z/p	CG Mean ± SD	Z/p
FAAM-ADL (%)	Pre	76.11 ± 8.57	-2.68	80.00 ± 7.50	-2.80	82.50 ± 5.89	-1.00
	Post	90.33 ± 5.09	**0.007**	91.66 ± 5.59	**0.005**	83.00 ± 6.32	0.317
FAAM-S (%)	Pre	70.55 ± 12.10	-2.68	73.33 ± 5.00	-2.69	78.00 ± 4.83	-1.73
	Post	85.55 ± 9.82	**0.007**	88.33 ± 2.50	**0.007**	79.50 ± 4.37	0.083

Data expressed as mean ± standard deviation. FAAM: Foot and Ankle Ability Measure ADL: Activity of Daily Living S: Sports SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group.

4.3.2. Intragroup Comparison of Pre and Post-Measurements Findings for Balance Error Scoring System

Comparing the pre and post-measurement findings of the single-leg stance on the firm surface for stable ankle were demonstrated that a statistically significant difference was found in the SG group (Table 4.9). The differences between pre and post-measurement for the unstable ankle was found statistically significant in SG and UG. When pre and posttest findings on the foam surface of both ankles were examined, statistically significant differences were found in SG and UG.

When the pre and post-measurement findings of the tandem stance on the firm surface condition for the unstable ankle were compared, a statistically significant difference was found in SG and CG groups. No statistical difference was found between pre and posttest findings of the stable ankle for this condition in any group. For the foam surface condition, the differences between pre and posttest findings for the stable ankle was found statistically significant in SG and UG. For pre and posttest findings of the unstable ankle, there were statistically significant differences in all groups.

Statistically significant differences were found in the BESS total scores of both ankles between pre and posttest findings in SG and UG.

Table 4.9. Intragroup Comparison of Pre-Measurement Findings for Balance Error Scoring System

Conditions (score)				SG Mean ± SD	t/p	UG Mean ± SD	t/p	CG Mean ± SD	t/p
Double Leg Stance	**Firm**		**Pre**	0.00	-	0.00	-	0.00	-1.00*/0.317
			Post	0.00		0.00		0.50 ± 1.58	
	Foam		**Pre**	0.22 ± 0.44	-1.41*/0.157	0.66 ± 2.00	-1.00*/0.317	0.90 ± 1.52	-
			Post	0.00		0.00		1.10 ± 1.59	
Single Leg Stance	**Firm**	**Stable**	**Pre**	2.88 ± 2.42	-3.50/**0.008**	1.66 ± 1.00	-0.35/0.729	2.20 ± 1.93	0.80/0.443
			Post	1.33 ± 1.41		1.55 ± 1.13		2.40 ± 1.71	
		Unstable	**Pre**	4.22 ± 2.58	-3.77/**0.005**	3.44 ± 1.87	-3.91/**0.004**	4.10 ± 2.33	0.92/0.381
			Post	2.66 ± 1.93		1.33 ± 1.11		4.60 ± 2.45	
	Foam	**Stable**	**Pre**	6.44 ± 1.74	-6.48/**0.000**	6.44 ± 1.87	-3.41/**0.009**	7.10 ± 1.72	-1.86/0.096
			Post	4.00 ± 0.86		5.55 ± 2.35		6.60 ± 1.50	
		Unstable	**Pre**	8.55 ± 1.23	-5.36/**0.001**	7.33 ± 1.58	-4.09/**0.003**	8.60 ± 1.07	1.40/0.193
			Post	6.55 ± 1.01		5.55 ± 1.42		8.90 ± 1.10	

Tandem Stance	**Firm**	**Stable**	**Pre**	0.33 ± 0.50	-1.41*/0.157	0.66 ± 1.00	-1.63*/0.102	1.20 ± 1.68	-1.34*/0.180
			Post	0.11 ± 0.33		0.22 ± 0.44		0.90 ± 1.19	
		Unstable	**Pre**	1.55 ± 1.50	-2.53*/**0.011**	2.00 ± 3.08	-2.23*/**0.026**	2.40 ± 2.31	-2.12*/**0.034**
			Post	0.55 ± 0.72		0.33 ± 0.70		1.70 ± 2.21	
	Foam	**Stable**	**Pre**	2.66 ± 1.50	-4.91/**0.001**	3.77 ± 1.85	-3.33/**0.010**	4.80 ± 1.54	-1.86/0.096
			Post	1.22 ± 1.30		2.11 ± 1.16		4.30 ± 1.70	
		Unstable	**Pre**	4.22 ± 1.30	-3.83/**0.005**	4.77 ± 2.63	-2.44/**0.041**	6.50 ± 1.90	-2.68/**0.025**
			Post	2.77 ± 1.71		2.33 ± 2.34		5.80 ± 2.20	
BESS Total	**Stable**		**Pre**	12.55 ± 2.92	-9.29/**0.000**	13.22 ± 4.46	-4.15/**0.003**	16.20 ± 5.09	-0.39/0.699
			Post	6.66 ± 2.00		9.44 ± 3.50		15.80 ± 4.58	
	Unstable		**Pre**	18.77 ± 3.89	-12.60/**0.000**	18.22 ± 7.69	-3.17/**0.013**	22.50 ± 5.75	0.09/0.924
			Post	12.55 ± 3.32		9.55 ± 2.40		22.60 ± 7.94	

Data expressed as mean ± standard deviation. BESS: Balance Error Scoring System SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Wilcoxon Test

4.3.3. Intragroup Comparison of Pre and Post-Measurements Findings for Y Balance Test

According to paired sample t-test results and Wilcoxon test, there were significant differences for intragroup variables between study groups to reach distance in the anterior, PM and PL directions (Table 4.10). The differences between pre and post-measurements for reach distance in the anterior direction in both ankles was found statistically significant in SG and UG. These results showed that athletes in SG and UG demonstrated better dynamic balance performance in anterior direction after balance exercise training for regardless of right or left foot. There was no statistical difference between pre and posttest findings in the CG.

For the mean values of reach distance in PM direction of both ankles, there were statistical differences between pre and post-measurements in SG and UG (Table 4.10). The results demonstrated that the means of reach distance were increased in both groups compared to the CG.

When the pre and post-measurement findings of reach distance in PL direction of the stable ankle were compared, a statistically significant difference was found in the SG group (Table 4.10). Whereas, no statistical difference was found between pre and posttest findings of the stable ankle for this direction in UG and CG. For the mean values of reach distance in PM direction of the unstable ankle, SG and UG had statistical differences between pre and posttest findings in contrast to CG.

Table 4.10. Intragroup Comparison of Pre and Post-Measurements Findings for Y Balance Test

Y Balance Test (cm)			SG Mean ± SD	t/p	UG Mean ± SD	t/p	CG Mean ± SD	t/p
Anterior	**Stable**	**Pre**	78.01 ± 8.17	-2.66*	79.83 ± 2.27	-2.38*	77.55 ± 6.38	-0.41*
		Post	86.58 ± 5.46	**0.000**	83.62 ± 4.02	**0.017**	77.65 ± 7.14	0.678
	Unstable	**Pre**	75.95 ± 7.97	5.06	76.90 ± 4.69	3.52	73.85 ± 6.89	0.47
		Post	83.29 ± 5.51	**0.001**	82.29 ± 4.75	**0.008**	74.25 ± 7.14	0.648
Posteromedial	**Stable**	**Pre**	94.10 ± 7.26	8.80	95.28 ± 10.22	3.09	95.38 ± 6.72	-0.48
		Post	104.36 ± 8.48	**0.000**	102.22 ± 11.73	**0.015**	95.02 ± 7.64	0.639
	Unstable	**Pre**	92.08 ± 9.18	5.83	91.51 ± 8.81	4.41	91.03 ± 5.91	0.87
		Post	102.25 ± 8.64	**0.000**	102.21 ± 11.37	**0.002**	91.97 ± 7.55	0.406
Posterolateral	**Stable**	**Pre**	88.20 ± 8.73	7.03	91.26 ± 7.70	1.99	88.65 ± 8.20	-0.50
		Post	98.27± 7.90	**0.000**	95.67 ± 7.32	0.081	88.24 ± 7.33	0.625
	Unstable	**Pre**	86.04 ± 8.65	6.17	87.13 ± 8.80	3.19	86.87 ± 6.67	-0.79
		Post	93.54 ± 8.56	**0.000**	94.65 ± 8.01	**0.013**	85.87 ± 6.09	0.446

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Wilcoxon Test

4.3.4. Intragroup Comparison of Pre and Post-Measurements Findings for Jump and Hop Tests

A paired sample t-test and Wilcoxon test were executed to examine changes of each group across the pre and post-measurements on jump and hop tests. Comparing the pre and posttest results of the Vertical Jump Test for the unstable ankle were demonstrated that a statistically significant difference was observed only in the UG group (Table 4.11). These results showed positive improvements in vertical jump performance of athletes in the UG group. There was no statistically significant difference between the pre and posttest findings for stable ankle in all groups.

When the pre and post-measurement findings of figure-of-eight test of the stable ankle were compared, statistically significant differences were found in SG and CG group (Table 4.11). Both groups demonstrated significant improvement in time after the rehabilitation for stable and unstable ankle. Whereas, the CG showed no significant change in time for both ankles according to the findings.

Statistically significant differences were determined between pre and post-measurements in relation to stable and unstable ankle for Side Hop Test values in all groups (Table 4.11). These results demonstrated significant improvement in side hop performance of all groups regardless of rehabilitation.

Table 4.11. Intragroup Comparison of Pre and Post-Measurements Findings for Jump and Hop Tests

			SG Mean ± SD	t/p	UG Mean ± SD	t/p	CG Mean ± SD	t/p
Vertical Jump (cm)	**Stable**	**Pre**	30.17 ± 10.23	-2.19*	26.46 ± 5.26	-2.10*	28.24 ± 8.99	-1.33*
		Post	31.77 ± 9.85	**0.028**	29.42 ± 6.05	**0.035**	28.89 ± 8.57	0.182
	Unstable	**Pre**	30.74 ± 9.67	-1.54*	25.50 ± 4.53	-2.45*	26.88 ± 9.36	-1.73*
		Post	31.68 ± 9.34	0.123	28.75 ± 4.89	**0.014**	28.39 ± 8.82	0.083
Figure-8 Hop (sec)	**Stable**	**Pre**	11.79 ± 1.96	-8.93	11.62 ± 1.07	-8.00	11.78 ± 0.76	-1.78
		Post	10.32 ± 2.04	**0.000**	11.01 ± 1.12	**0.000**	11.51 ± 0.90	0.109
	Unstable	**Pre**	12.51 ± 1.72	-5.66	12.57 ± 1.54	-6.37	12.41 ± 0.78	-1.46
		Post	11.29 ± 1.40	**0.000**	11.10 ± 1.20	**0.000**	12.09 ± 1.05	0.176
Side Hop (sec)	**Stable**	**Pre**	10.28 ± 1.85	-5.15	10.15 ± 1.53	-5.00	10.34 ± 1.06	-2.84
		Post	8.26 ± 1.06	**0.001**	8.74 ± 1.01	**0.001**	9.75 ± 0.93	**0.019**
	Unstable	**Pre**	10.81 ± 2.13	-3.95	10.80 ± 1.79	-5.49	10.92 ± 1.11	-2.44
		Post	8.67 ± 0.81	**0.004**	8.25 ± 0.95	**0.001**	10.46 ± 1.30	**0.037**

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Wilcoxon Test

4.4. Intergroup Comparison of Difference between Pre and Post-Measurements Findings

4.4.1. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Foot and Ankle Ability Measure

The One-way ANOVA and Tukey post hoc test was used to compare the difference between pre and post measurements findings of FAAM-ADL and FAAM-S between groups (Table 4.12) As a result of the statistical analysis, statistically difference was found between the groups in mean values of FAAM-ADL and FAAM-S. It was determined that SG and UG had higher the mean of FAAM-ADL and FAAM-S scores compared to the CG according to Tukey's HSD post hoc test. However, there was no statistical difference between SG and UG.

Table 4.12. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for FAAM

	SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Δ FAAM-ADL (%)	14.22 ± 8.61	11.66 ± 3.53	0.50 ± 1.58	19.57*	**0.000**
Δ FAAM-S (%)	15.00 ± 7.50	15.00 ± 5.00	1.50 ± 2.41	20.84	**0.000**

Data expressed as mean ± standard deviation. BESS: Balance Error Scoring System SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.4.2. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Balance Error Scoring System

Table 4.13 was demonstrated the difference in BESS values pre and post measurements between groups. A statistically significant difference in intergroup variables was observed in terms of pre and posttest findings of the single-leg stance on firm and foam surfaces for the stable ankle. A Tukey's HSD post hoc test revealed that the error was statistically significantly lower after rehabilitation for stable ankle (SG) compared to rehabilitation for unstable ankle (UG) and the CG. There was no statistically significant difference between the UG and CG. According to variables of the unstable ankle, no statistical difference was found between the SG and UG. However, there was a statistical difference between SG and CG in relation to the single-leg stance on foam surface between pre and posttest findings in contrast to CG. For the tandem stance on the firm and foam surfaces condition of both ankles, no statistical difference was found for intergroup variables. A statistically significant difference in intergroup variables was observed in terms of pre and posttest findings of the BESS Total. It was determined that SG and UG had lower the mean of BESS Total scores compared to the CG. However, there was no statistical difference between SG and UG.

Table 4.13. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for BESS

Conditions (score)		SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Δ Double Leg stance	**Firm**	0.00	0.00	0.50 ± 1.58	1.80*	0.407
	Foam	-0.22 ± 0.44	-0.66 ± 2.00	0.20 ± 1.39	0.31*	0.855
Δ Single Leg Stance Firm	**Stable**	-1.55 ± 1.33	-0.11 ± 0.92	0.20 ± 0.78	11.25*	**0.004**
	Unstable	-1.55 ± 1.23	-2.11 ± 1.61	0.50 ± 1.71	13.32*	**0.001**
Δ Single Leg Stance Foam	**Stable**	-2.44 ± 1.13	-0.88 ± 0.78	-0.50 ± 0.84	11.35	**0.003**
	Unstable	-2.00 ± 1.11	-1.77 ± 1.30	0.30 ± 0.67	14.02	**0.000**
Δ Tandem Stance Firm	**Stable**	-0.22 ± 0.44	-0.44 ± 0.72	-0.30 ± 0.67	0.51*	0.774
	Unstable	-1.00 ± 0.86	-1.66 ± 2.50	-0.70 ± 0.94	1.44*	0.485
Δ Tandem Stance Foam	**Stable**	-1.44 ± 0.88	-1.66 ± 1.50	-0.50 ± 0.84	3.00	0.068
	Unstable	-1.44 ± 1.13	-2.44 ± 3.00	-0.70 ± 0.82	5.90*	0.052
Δ BESS Total	**Stable**	-5.88 ± 1.90	-3.77 ± 2.72	-0.40 ± 3.16	10.23	**0.001**
	Unstable	-6.22 ± 1.48	-8.66 ± 8.20	0.10 ± 3.21	18.44*	**0.000**

Data expressed as mean ± standard deviation. BESS: Balance Error Scoring System SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

4.4.3. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Y Balance Test

According to The One-way ANOVA and Tukey post hoc test results, there were significant differences for intergroup variables between study groups to reach distance in the anterior, PM and PL directions (Table 4.14).

The differences between pre and post-measurements for reach distance in the anterior direction in stable ankles was found statistically significant between all groups. These results showed that athletes in SG demonstrated better dynamic balance performance in anterior direction after balance exercise training in compared to UG and CG. In contrast to the CG, the athletes in UG performed better in the anterior direction. For the unstable ankle, there was statistically significant difference between UG and CG according to post hoc test results.

For differences in the mean values of reach distance in PM direction of both ankles, statistical differences were observed between all groups. The results demonstrated that the means of reach distance were increased in both groups in compared to the CG.

When the difference of pre and posttest findings of reach distance in PL direction of both ankles were compared, statistically significant differences were found between groups. For the difference in the mean values of reach distance in PL direction of the stable ankle, SG had greater reach distance in contrast to UG and CG. Whereas, no statistical difference was found differences of pre and posttest findings of the stable ankle for this direction in UG and CG. When the unstable ankle was considered, there also were statistical different intergroup variables. This difference was due to the fact that the mean value of SG and UG was higher than the CG.

Table 4.14. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Y Balance Test

Y Balance Test (cm)		SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Δ Anterior	Stable	8.56 ± 4.09	3.79 ± 3.33	0.10 ± 1.44	17.52	**0.000**
	Unstable	4.58 ± 5.58	8.91 ± 3.91	0.40 ± 2.69	9.80	**0.001**
Δ PM	Stable	10.25 ± 3.49	6.93 ± 6.73	-0.36 ± 2.37	13.82	**0.000**
	Unstable	10.17 ± 5.23	10.70 ± 7.27	0.93 ± 3.40	16.32*	**0.000**
Δ PL	Stable	10.07 ± 4.29	4.40 ± 6.62	-0.41 ± 2.57	14.37*	**0.001**
	Unstable	8.12 ± 4.15	7.07 ± 7.06	-0.99 ± 3.96	8.84	**0.001**

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. PM: Posteromedial PL: Posterolateral
*Kruskal Wallis-H Test

4.4.4. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Jump and Hop Tests

When the difference of pre and posttest findings of the vertical jump test both ankles were compared, no statistically significant difference was found between groups (Table 4.15).

For figure-eight hop test for both ankles, there was a statistically significant difference between groups for stable ankle and unstable ankle. The athletes in the SG completed the test for the stable ankle less time than the other groups. For the unstable ankle, SG and UG had similar improvements in time compared with the CG.

It was determined that there were statistically significant differences between the groups in terms of the difference between pre and posttest findings of Side Hop Test for both ankles. According to post hoc test, SG demonstrated better hopping performance on the stable ankle compared to the CG. For the mean difference value of side hop test for the unstable ankle, SG and UG had greater improvements in compared with CG. There was no statistically significant difference between SG and UG in terms of sports performance tests.

Table 4.15. Intergroup Comparison of Difference between Pre and Post-Measurements Findings for Jump and Hop Tests

		SG Mean ± SD	UG Mean ± SD	CG Mean ± SD	F	p value
Δ Vertical Jump (cm)	**Stable**	1.59 ± 2.69	2.96 ± 4.66	0.64 ± 1.43	2.43*	0.296
	Unstable	0.94 ± 2.14	3.25 ± 2.98	1.51 ± 2.66	1.89	0.171
Δ Figure-of-8 Hop (sec)	**Stable**	-1.47 ± 0.49	-0.61 ± 0.22	-0.27 ± 0.48	19.66	**0.000**
	Unstable	-1.21 ± 0.64	-1.46 ± 0.69	-0.31 ± 0.68	7.76	**0.002**
Δ Side Hop (sec)	**Stable**	-2.01 ± 1.17	-1.41 ± 0.84	-0.59 ± 0.65	5.90	**0.008**
	Unstable	-2.14 ± 1.62	-2.55 ± 1.39	-0.45 ± 0.59	7.43	**0.003**

Data expressed as mean ± standard deviation. SG: Rehabilitation for Stable Ankle Group, UG: Rehabilitation for Unstable Ankle Group, CG: Control Group. *Kruskal Wallis-H Test

5. DISCUSSION

The main aim of this study was to examine the effectiveness of the 4-week unilateral balance exercise training on bilateral balance and explosive power among athletes with CAI and to compare the outcomes of this program on unilateral training for stable ankle (SG) and unstable ankle (UG). Overall, our hypothesis is supported by data. For the FAAM-ADL, FAAM-S, BESS single leg and tandem stance conditions and BESS Total scores, anterior, PM and PL directions in Y Balance Test, vertical jump, Figure-of-8 Test and Side Hop Test, athletes in the rehabilitation groups showed better performance over time, and this did not depend on which ankle was rehabilitated. Athletes in the control group (CG) demonstrated alteration overtime for the BESS tandem stance on both surfaces for the unstable ankle and Side Hop Test for both ankles. The improvements were greater among athletes in both rehabilitation groups applied to the stable ankle and to the unstable ankle. These findings propose that the unstable ankle improved although athletes were rehabilitated for the stable ankle only**.**

The validity of the study findings is strengthened by both the randomization of the groups and the fewness of intergroup differences in our pre-measurement findings. There were no statistical differences in age, body height, the mean of CAIT scores for both ankles, number of ankle sprain history, playing time in their sports branch, the distribution of gender and dominance of hand and foot between groups. However, statistical differences were found in weight, accordingly BMI and BESS tandem stance on the foam surface condition for the stable ankle between groups. This statistical difference was due to the difference of findings between SG and CG. The number of ankle sprain history and static balance were not found considerably related to the ankle sprain injury. In the literature, several studies have shown that BMI is an important predictor of ankle sprain injuries (114–116). Gribble et al. indicated the cutoff score of BMI as 26.69 kg/m^2 (114). Also, these studies have found that male college athletes had a higher risk of ankle sprains with greater BMI score and lesser reach distance of the YBT anterior. For female college athletes, these variables were not found as significantly related to the ankle sprains (114,116). In another study, BMI and female gender also have an impact on static postural control (117). According to the literature, pre-test results in terms of BMI and tandem stance condition may be related to each other in our study.

The presence of bilateral improvements in our study can be explained for several possible reasons. Alteration and adaptations in the central pathways of the CNS are probably the main cause of the bilateral improvements observed. Researchers (16,74) have claimed that changes at the spinal or supraspinal level may occur after an injury. After acute ankle sprain, bilateral postural control deficits may result from these central alterations (16). With proper strong evidenced rehabilitation, the alteration of neuromuscular re-education can be possible by enhancing the central processing and the efferent response to the afferent somatosensory input. Several authors (15,75,102,118) have found that bilateral improvements in function and NMC in individuals with CAI following unilateral exercise training. Ozsezikli et al. have suggested that the perturbation increases the prefrontal circulation which is activated during central input processing and motor planning. Therefore, this result may be considered as an increase in activity in the task-related neural centers and a parallel effect of plasticity (119). Even though it is clear that unilateral exercise training produces bilateral improvement in balance and sports performance, the mechanisms behind these improvements remain unclear. The improvements measured in the present study are unlikely to arise from the athletes who independently trained the unstable ankle because before the study, the athletes were informed that they were not allowed to perform training outside the supervised session and after the study it was confirmed that they did not perform training during their sessions. Since athletes with CAI in the CG have been reported to be stable between pre and post-measurement, few improvements demonstrated by CG and the outcome measures of our study are explained by neither natural healing nor a learning effect.

Although several studies have revealed bilateral improvements after unilateral exercise training, studies investigating improvements on unstable ankle training to stable ankle are limited. This study is the first to evaluate sports performance in athletes with CAI, who especially playing in team sports and to compare the stable ankle and unstable ankle training. Given the possible deterioration of ligamentous structures, local mechanoreceptors, and consequently dynamic stabilizers in the injured ankle, it was not clear enough whether the improvement on the unstable ankle was seen after training the stable ankle. One of the reasons may be that if only the stable ankle of the patients was trained, their levels of motivation, confidence, and anxiety would limit the function and performance on the unstable ankle. Hale et al. have evaluated whether training only the stable ankle showed an therapeutically beneficial effect on the unstable ankle. They have reported that balance exercise training the stable ankle demonstrated the same therapeutic effect on the unstable ankle in terms of level of function, static and dynamic balance. This study is the first to elicit evidence that balance exercise training of the stable ankle may provide improvements in sports performance in addition to previous studies. Our findings also support some researches (82,83,120) that only 4-week of rehabilitation may provide achievement in alterations in the central mechanism of neuromuscular control.

According to present study, the athletes in SG and UG showed greater improvement across time in mean values of the functional limitation scales of the FAAM-ADL (respectively 15.06-point change (14.22%) and 9,79-point change (11.66%)) and FAAM-S (4.8-point change (15.0%) for both groups) regardless of which ankle is trained. We hypothesize that the FAAM-ADL and FAAM-S scores of both rehabilitation groups demonstrated such a significant improvement in comparison with the control group and that the rehabilitation given regardless of stable or unstable ankle improved in the unstable ankle. The control group showed only a 0.42-point change (0.50%) on the FAAM-ADL and a 0.48-point change (1.50%) on the FAAM-S. The minimal clinically important differences (MCID) for FAAM-ADL and FAAM-S is reported to have an MCID of 8 points for the ADL subscale and 9 points for the sports subscale (107). A validity study (106) reported that the FAAM-ADL and FAAM-S were reliable to use in detection of self-reported functional dysfunctions associated with CAI. Minimally clinically important difference values were reached with only FAAM-ADL in our findings so clinically relevant changes over the 4-week training were noted in SG and UG groups. Minoonejad et al. have reported that 6-weeks of balance training including hop stabilization exercises have found to effectively improve self-reported function and NMC in college basketball players with CAI (81). Anguish et al. have also found that 4-week balance training program involving traditional single-legged balance training or progressive dynamic balance training for individuals with CAI demonstrated similar improvements in the lower extremity function especially in FAAM-S (85).

In general, the performance of the athletes on the BESS also indicates a therapeutic benefit of the balance exercise training program. The improvements were detected in the performance of the tandem stance foam surface condition for all groups and ankles. Our these findings in BESS are supported by Hale et al. (15) have found the improvement only in findings of the tandem stance foam surface condition for both ankles in both rehabilitation groups and control group. Docherty et al. (110) also found the BESS has been sensitive to reveal differences between stable and unstable ankles among individuals with CAI. Contrary to the results of Hale et al, the athletes in SG and UG demonstrate the improvements in all condition of the BESS with the exception of the single-leg stance on a firm for stable ankle. It is possible to suggest that 4-week balance training for individuals or athletes with CAI can be considered in order to improve the static balance of unstable ankle, regardless of which ankle is trained.

Dynamic balance which was assessed by Y Balance Test in anterior, PM and PL directions improved by the athletes in SG and UG. Researchers (121) have presented evidence that the Y Balance Test is sensitive for assessing musculoskeletal impairments, like chronic ankle instability. Statistically significant differences have found in our results in terms of the reach distances in the anterior, PM and PL directions between groups. In all direction, there was an improvement between pre and posttest finding in SG and UG. Also, our findings were supported by Hale et al. (15) that have observed the improvement in the anterior and PM reach distance by training only the stable ankle. Otherwise, when uninjured ankle is considered, some researches investigated 4-weeks balance exercise program on individual with CAI by using SEBT. At the end of the program, they have found that improvements have been observed in function and dynamic postural control. Also, there is evidence that SEBT may be effective evaluation method to follow the change after rehabilitation for the CAI (82–85). These results show that regardless of which ankle is used for balance training, there is an improvement in balance on the unstable ankle.

Sports performance including vertical and horizontal jumping of the athletes in our study was evaluated by Countermovement Jump Test, Figure-of-8 Hop, and Side Hop Tests. According to our findings, statistically significant differences were observed between pre and post-measurement in SG and UG in terms of CMJ and Figure-of-8 Hop Test. In results of Side Hop Test, all group demonstrated the improvement in time between pre and post-measurement. When we consider the differences intergroup, the improvement was not observed in CMJ findings. SG and UG showed better performance compared to the CG. For the stable ankle, especially SG performed much better than other groups. These 3 functional tests were chosen depending on their ability to create stress the lateral side of the ankle and to recreate the mechanisms that may cause the experience of FI (113,122). All those tests were timed over a set course or distance, as we categorized the tests as muscular power and agility movements. Agility maneuvers include rapid and sudden direction changes occurring in response to a stimulus, which is an essential component in several competitive sports (113). Particularly with CAI, these tests may consist of the movements during sports activity leading to sensation of giving away and instability. Previous CAI researches have used single-legged functional tests based on agility tests like the single leg hopping course (123) or power tests such as the single leg hop test (122). Docherty et al. (122) showed the presence of a relationship between the level of self-reported ankle function and Figure-8 hop and Side hop tests performance. Also they have found performance deficits in terms of agility in individuals with CAI. However, others have found no significant difference in many agility and hopping tasks or muscular power performance between those with and without CAI (124,125).

Although our data suggest that there is a cross-effect on the unstable ankle after stable ankle training, further research is needed. Researchers should establish ideal treatment guidelines to maximize function, accelerate the return to sports, and decrease the risk of re-injury. It is difficult to examine the literature to determine the optimal treatment guideline because there is excessive variability in the methods to be used. Our results and others' studies (15,82–84,120) claims that balance improvements occur after only 4 weeks of training. When we compare our results with researchers using the similar assessment methods in individuals or athletes who have completed a 6-week rehabilitation program, it is not clear whether a longer intervention time will yield better consequences. Besides, the improvement in studies involving a 4-week of training program may be due to low fitness levels of individuals and amateur athletes. Professional athletes who have high athletic performance may not show the same improvement over a 4-week period. It is also difficult to determine the optimal number of rehabilitation sessions due to variations of treatment guidelines, assessment methods and outcome measures and conflicting evidences about dose-response relationship. Hale et al. (15) conducted a study similar to ours, investigated the effects of balance exercise training on the FADI and SEBT scores. The participants like our participants completed the training program only 8 sessions in 4 weeks.

Future researches including a more various athletic population in different sports branches also will support to validate our findings. In particular, researchers should examine individuals or athletes with acute LAS and with/out mechanical instability. In addition, future researches should evaluate study populations with unilateral and bilateral ankle instability, and amateur and professional athletes groups with different branches and activity levels.

By training only the stable or uninjured ankle, clinicians are able to start NMC retraining before completing the acute phase of healing, before allowing individuals to weight-bearing on the injured or unstable ankle, or even with other precautions or contraindications to exercise because of their injuries. Athletes with history of chronic injuries can initiate the training protocols on the stable ankle by performing functional and NMC retraining at higher levels. It is possible that these activities are initiated on the stable ankle will bring about earlier improvements in function and postural control on the unstable ankle. In this way, shorter rehabilitation times, early return to sports and reduction in health care costs may be possible. This can also provide psychosocial benefits by facilitating individuals to participate in functional training earlier, encouraging a continuous connection with activities that motivate the individual.

The limitations of our study;

-The long follow-up results were needed to evaluate the long-term effects of the balance exercise training applied to only stable ankle and only unstable ankle.

6. CONCLUSION

- Lower extremity function, static and dynamic balance, sports performance including explosive power on the injured side can be improved with balance training including balance and hop stabilization exercises applied to both only the stable ankle and only the unstable ankle.
- The differences in all variables were similar in the stable ankle rehabilitation group and unstable rehabilitation groups.
- Vertical jump performance on the unstable ankle may be improved with balance exercise training applied to the unstable ankle.
- The balance exercise training applied to both the stable and unstable ankle alone may improve not only the unstable ankle but also the stable ankle, but the improvement was higher in the stable ankle rehabilitation group.
- Only 4-week of balance exercise training can provide bilateral improvements in terms of functionality, static and dynamic balance and explosive power in athletes with CAI.
- The balance training involving balance and hop stabilization exercises can be recommended to clinicians to include the stable ankle rehabilitation as a part of the comprehensive rehabilitation strategy for individuals or athletes with CAI to avoid losing lower extremity functions and sports performances.

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8. APPENDIXES

8.1. Appendix 1 Informed Written Consent

ARAŞTIRMAYA KATILIM ONAM FORMU

Bu çalışma İstanbul Üniversitesi Tıp Fakültesi Spor Hekimliği Anabilim Dalı ve Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Spor Fizyoterapisi Bölümü tarafından yürütülen **"Kronik ayak bileği instabilitesi olan sporcularda unilateral denge eğitiminin bilateral denge ve patlayıcı güç üzerine etkisi"** başlıklı araştırma kapsamında planlanmıştır. Bu çalışmanın amacı, 4 haftalık tek taraflı denge egzersiz eğitim programının kronik ayak bileği instabilitesi olan atletlerdeki bilateral denge ve patlayıcı gücü üzerindeki etkilerini araştırmaktır. Çalışmamıza katılmayı kabul eden gönüllü bireylerin; yaşı, cinsiyeti, sosyo-demografik koşulları, var olan kronik hastalıkları, geçirilen cerrahi durumları, yaralanmaları ve antrenman davranışlarına dair bilgiye ulaşılarak, tedavi planına dahil edilecektir. Deney grubuna katılacak olan bireyler 4 hafta süreyle egzersiz eğitimi alacaktır. Bu amaçla kullanılan değerlendirmelerin sonuçları yalnızca araştırma kapsamındaki çalışmalarda kullanılacaktır.

Araştırma ile ilgili sizden doldurmanızı istediğimiz formları doğru bir şekilde doldurmanızı ve herhangi bir şikayetiniz ya da rahatsızlığınız olduğunda bize bildirmeniz gerekmektedir. İstediğiniz zaman çalışma dışına çıkma hakkınız olduğunu bilmenizi isteriz. Bu araştırma kapsamında uygulanacak olan uygulamalarda herhangi bir risk bulunmamakta ve yapılacak hiçbir uygulama size zarar vermeyecektir. Bu araştırma dahilinde sizden herhangi bir ücret talep edilmemektedir. Bu araştırmada yer almanız nedeniyle size hiçbir ödeme yapılmayacaktır. Kişisel bilgileriniz herhangi bir amaçla, kurum yöneticileri veya üçüncü kişilerle paylaşılmayacaktır.

Katılımınız için teşekkür ederiz.

Sorumlu araştırmacı: Prof. Dr. Gökhan Metin

Yardımcı Araştırmacı: Fzt. Ayça Yağcıoğlu - 0543 280 0692 (24 saat ulaşılabilecek kişi)

"Kronik ayak bileği instabilitesi olan sporcularda unilateral denge eğitiminin bilateral denge ve patlayıcı güç üzerine etkisi" isimli çalışmada katılımcıya/gönüllüye verilmesi gereken bilgileri okudum ve katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. **Çalışma hakkında yazılı ve sözlü açıklama adı belirtilen araştırmacı tarafından yapıldı.** Bu çalışmayı istediğim zaman ve herhangi bir neden belirtmek zorunda kalmadan bırakabileceğimi ve bıraktığım takdirde herhangi bir olumsuzluk ile karşılaşmayacağımı anladım.

Bu koşullarda söz konusu araştırmaya kendi isteğimle, hiçbir baskı ve zorlama olmaksızın katılmayı kabul ediyorum.

Gönüllünün Adı /Soyadı /İmzası /Tarih

Açıklama Yapan Kişinin Adı /Soyadı /İmzası /Tarih

8.2. Appendix 2 Ethical Committee Approval

T.C. YEDİTEPE ÜNİVERSİTESİ

Sayı : 37068608-6100-15- 1609
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

14/02/2019

İlgili Makama (Ayça Yağcıoğlu)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü Prof. Dr. Feryal Subaşı'nın sorumlu olduğu **"Kronik Ayak Bileği İnstabilitesi Olan Sporcularda Unilateral Denge Eğitiminin Bilateral Denge ve Patlayıcı Güç Üzerine Etkisi"** isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası (**1564** kayıt Numaralı KAEK Başvuru Dosyası), Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **13.02.2019** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 961**).

Prof. Dr. Turgay ÇELİK
Yeditepe Üniversitesi
Klinik Araştırmalar Etik Kurulu Başkanı

Yeditepe Üniversitesi 26 Ağustos Yerleşimi, İnönü Mahallesi Kayışdağı Caddesi 34755 Ataşehir / İstanbul
T. 0216 578 00 00 www.yeditepe.edu.tr F. 0216 578 02 99

8.3. Appendix 3 Structured Questionnaire for Patient's Demographic Characteristics

Yeditepe Üniversitesi

Sağlık Bilimleri Enstitüsü

Fizyoterapi ve Rehabilitasyon Anabilim Dalı

Bölüm 1. Demografik Özellikler Tarih :…/….. /………

1) Sporcunun Adı Soyadı: …………………… Telefonu:

2) Doğum Tarihi:

3) Cinsiyet: ( ) Kadın ( ) Erkek

4) Boy uzunluğu (cm):

5) Vücut ağırlığı (kg) :

6) Dominant taraf: El ( ) sağ ( ) sol

Ayak ( ) sağ ( ) sol

7) Spor Dalı: ……..

8) Kaç yıldır bu sporu yapmaktasınız? Amatör................ Profesyonel.............

9) Yapmakta olduğunuz spor dalında hangi pozisyonda oynuyorsunuz? ....

10) Herhangi bir sürekli hastalığınız var mı? Varsa hangileri?

( ) Sürekli bir hastalığım yok

( ) Romatizma ( ) Ortopedik hastalık ( ) Nörolojik problemler

( ) Travma ( ) Diğer...........

11) Herhangi bir ameliyat geçirdiniz mi? ( ) Evet........... Belirtiniz ( ) Hayır

12) Hiç kaza geçirdiniz mi ? ( ) Evet........Belirtiniz ( ) Hayır

13) Son 3 ayda bir sakatlanma geçirdiniz mi?

( ) Evet ( ) Hayır

14) Evet ise, ne tarz bir sakatlanma geçirdiniz?.....................

15) Antreman sıklığınız?

( )Haftada 1 kez ( )Haftada 2-3kez ( )Haftada 4-5 kez ( )Her gün

16) Yaptığınız antreman her seferinde kaç dakika sürüyor?

( )30 – 60 dk ( )60 – 90 dk ( )90 – 120 dk

17) Haftada ortalama kaç maç yapıyorsunuz? ....

18) Daha önce ayak bileğiniz burkuldu mu?

( ) Evet ( ) Hayır

19) Evet ise, kaç defa? ....

20) Daha önce ayak bileği instabilitesi için herhangi bir tedavi gördünüz mü?

( ) Evet ( ) Hayır

21) Kronik ayak bileği instabilitesi ile ilgili egzersiz programı yapıyor musunuz?

( ) Evet ( ) Hayır

22) Yapıyorsanız ne süredir yapmaktasınız?............

23) Yapıyorsanız ne tarz egzersizler yapıyorsunuz?...........

8.4. Appendix 4 Cumberland Ankle Instability Tool

		SAĞ	SOL
1)Ayak bileğim ağrıyor.	Hiçbir zaman		
	Spor sırasında		
	Düz olmayan zeminde koşarken		
	Düz zeminde koşarken		
	Düz olmayan zeminde yürürken		
	Düz zeminde yürürken		
2)Ayak bileğimde güvensizlik hissediyorum.		SAĞ	SOL
	Hiçbir zaman		
	Spor sırasında ara sıra		
	Spor sırasında sık sık		
	Günlük aktiviteler sırasında ara ara		
	Günlük aktiviteler sırasında sık sık		
3) Keskin dönüşler sırasında ayak bileğimi güvensiz hissediyorum.		SAĞ	SOL
	Hiçbir zaman		
	Koşarken ara sıra		
	Koşarken sıklıkla		
	Yürüdüğümde		
4)Merdiven inerken ayak bileğimi güvensiz hissediyorum.		SAĞ	SOL
	Hiçbir zaman		
	Hızlı indiğimde		
	Bazı durumlarda		
	Her zaman		
5) Tek ayak üzerinde durduğumda ayak bileğimi güvensiz hissediyorum		SAĞ	SOL
	Hiçbir zaman		
	Parmak ucunda		
	Normal basarken		
6) Ayak bileğimi güvensiz hissediyorum		SAĞ	SOL
	Hiçbir zaman		
	Yana sıçradığım zaman		
	İleriye sıçradığım zaman		
	Zıplayıp yere düştüğüm zaman		
7) Ayak bileğimi güvensiz hissediyorum		SAĞ	SOL
	Hiçbir zaman		
	Düz olmayan zeminde koşarken		
	Düz olmayan zeminde jog koşusu sırasında		
	Düz olmayan zeminde yürürken		
	Düz zeminde yürürken		
8) Ayak bileğim burkulur gibi olduğunda onu engelleyebiliyorum.		SAĞ	SOL
	Hemen		
	Çoğu zaman		
	Bazen		
	Hiçbir zaman		
	Hiç böyle bir his yaşamadım		
9) Ayak bileğim burkulur gibi olduktan sonra, ayak bileğim normale döner.		SAĞ	SOL
	Neredeyse hemen		
	1 günden kısa sürede		
	1-2 gün içinde		
	2 günden fazla sürede		
	Hiç böyle bir his yaşamadım		
	TOPLAM		

8.5. Appendix 5 Foot and Ankle Ability Measurement

AYAK VE AYAK BİLEĞİ KULLANILABİLİRLİK ÖLÇÜSÜ

Lütfen her soruya geçtiğimiz haftaki durumunuzu en iyi tanımlayan durumu işaretleyiniz. Eğer soruda sorulan aktiviteyi ayak ve ya ayak bileği dışındaki başka bir neden kısıtlıyorsa uygulanamaz olarak işaretleyiniz.

	Hiç zor değil	Hafif zor	Orta derece zor	Aşırı zor	Yapamıyorum	Uygulanamaz
Ayakta durmak	☐	☐	☐	☐	☐	☐
Düz zeminde yürümek	☐	☐	☐	☐	☐	☐
Düz zeminde ayakkabısız yürümek	☐	☐	☐	☐	☐	☐
Yokuş yukarı çıkmak	☐	☐	☐	☐	☐	☐
Yokuş aşağı inmek	☐	☐	☐	☐	☐	☐
Merdiven çıkmak	☐	☐	☐	☐	☐	☐
Merdiven inmek	☐	☐	☐	☐	☐	☐
Düz olmayan zeminde yürümek	☐	☐	☐	☐	☐	☐
Kaldırımdan inip- kaldırıma çıkmak	☐	☐	☐	☐	☐	☐
Çömelme	☐	☐	☐	☐	☐	☐
Ayak parmakları üzerinde durmak	☐	☐	☐	☐	☐	☐
Yürümeye başlamak	☐	☐	☐	☐	☐	☐
5 dakika ya da daha az yürümek	☐	☐	☐	☐	☐	☐
10 dakika kadar yürüme	☐	☐	☐	☐	☐	☐
15 dakika ve ya daha uzun yürümek	☐	☐	☐	☐	☐	☐

Ayak veya ayak bileği ağrısı yüzünde aşağıdakileri yaparken ne kadar zorluk çekiyorsunuz?

	Hiç zor değil	Hafif zor	Orta derece zor	Aşırı zor	Yapamıyorum	Uygulanamaz
Ev işleri	☐	☐	☐	☐	☐	☐
Günlük yaşam aktiviteler	☐	☐	☐	☐	☐	☐
Kişisel bakım	☐	☐	☐	☐	☐	☐
Hafif-orta düzeyde işler (ayakta durmak, yürümek)	☐	☐	☐	☐	☐	☐
Ağır işler (itme/çekme, tırmanma, taşıma)	☐	☐	☐	☐	☐	☐
Rekrasyonel (eğlence ve sosyal) aktiviteler	☐	☐	☐	☐	☐	☐

Eğer ayak ve ya ayak bileği problemi yaşamadan önceki durumunuza 100 puan verseniz, hiç ayak ve ya ayak bileği hareketi yapamamaya da 0 verseniz, şu anki durumuza 100 üzerinden kaç puan verirsiniz?

…%100

Ayak ve ayak bileği problemi yüzünden aşağıdaki aktiviteleri yaparken ne kadar zorluk çekiyorsunuz?

	Hiç zor değil	Hafif zor	Orta derece zor	Aşırı zor	Yapamıyorum	Uygulanamaz
Koşmak	☐	☐	☐	☐	☐	☐
Zıplamak	☐	☐	☐	☐	☐	☐
Atlama	☐	☐	☐	☐	☐	☐
Harekete aniden başlayıp durabilme	☐	☐	☐	☐	☐	☐
Makaslama ve yana doğrultulu hareketleri	☐	☐	☐	☐	☐	☐
Düşük seviyeli aktiviteler	☐	☐	☐	☐	☐	☐
Normal tekniğinizle aktiviteleri yapabilme	☐	☐	☐	☐	☐	☐
Sevdiğiniz sporu istediğiniz kadar yapabilme	☐	☐	☐	☐	☐	☐

Eğer ayak ve ya ayak bileği problemi yaşamadan önceki sportif durumunuza 100 puan verseniz, hiç ayak ve ya ayak bileği hareketi yapamamaya da 0 verseniz, şu anki sportif durumuza 100 üzerinden kaç puan verirsiniz?

…%100

Genel olarak şu anki fonksiyonunuzu nasıl değerlendirirsiniz?

☐ Normal ☐ Normale Yakın ☐ Anormal ☐ Ciddi Anormal

Malkoç M, Korkmaz O, Çelik D, Yalçın S.Turkish Translation and Adaptation of the Foot and Ankle Ability Measure. Acta Orthop Traumatol Turc. Oral presentation. Vol 48 (2014) p.76. Supplementum-I.

OrtoRehab.org

8.6. Appendix 6 Balance Error Scoring System Score Card

DENGE HATA SKORLAMA SİSTEMİ

AD SOYAD: **TARİH:**

SKORLAMA (Hatalar)	**SERT Yüzey**		**YUMUŞAK Yüzey**	
	ÖNCE	**SONRA**	**ÖNCE**	**SONRA**
İki Ayak Üzerinde Duruş				
Tek Ayak Üzerinde Duruş				
Tandem Duruş				
BESS TOPLAM:				

Denge Hata Skorlama Sistemi – Hata Çeşitleri
1. Elleri iliak krista üzerinden kaldırma 2. Gözleri açma 3. Adım atma, sendeleme veya düşme 4. Kalçayı >30 derece abdüksiyona getirme 5. Ön ayağı veya topuğu yerden kaldırma 6. Test pozisyonun > 5 sn dışında kalma
BESS, 20 saniyelik testler sırasında her bir hata için bir hata noktası ekleyerek hesaplanır.

Hangi ayak test edildi: □ Sağ □ Sol

8.7. Appendix 7 Sport Performance Tests Score Card

SAHA PERFORMANS TESTLERİ

Bacak Boyu Uzunluğu (cm): Sağ: Sol:

Y Balance Test

Yönler (cm)	İLK						SON					
	Sağ			Sol			Sağ			Sol		
Anterior												
Posteromedial												
Posterolateral												

Vertical Jump Test

Mesafe (cm)	İLK						SON					
	Sağ			Sol			Sağ			Sol		

Figure-of-8 Hop Test

Süre (sn)	İLK						SON					
	Sağ			Sol			Sağ			Sol		

Side Hop Test

Süre (sn)	İLK						SON					
	Sağ			Sol			Sağ			Sol		

Stabil Olmayan Ayak Bileği: □ Sağ □ Sol

8.8. Appendix 8 Curriculum Vitae

Kişisel Bilgiler

Adı	Ayça	**Soyadı**	Yağcıoğlu
Doğum Yeri	Malatya	**Doğum Tarihi**	08.12.1992
Uyruğu	T.C.	**TC Kimlik No**	43816317238
E-mail	ptaycayagcioglu@gmail.com	**Tel**	0543 280 06 92

Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora	-	-	-
Yüksek Lisans	-	-	-
Lisans	Fizyoterapi ve Rehabilitasyon	Yeditepe Üniversitesi	2016
Lise	-	Malatya Cumhuriyet Anadolu Lisesi	2010

Bildiği Yabancı Dilleri	Yabancı Dil Sınav Notu
İngilizce	87.5

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	Süre (Yıl - Yıl)
Lisansüstü Bursiyer	Yeditepe Üniversitesi	2016-2019
Araştırma Görevlisi	Yeditepe Üniversitesi	2019-Halen

Bilgisayar Bilgisi

Program	Kullanma becerisi
Microsoft Office Program	Çok iyi
SPSS	İyi

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

-

Diğer dergilerde yayınlanan makaleler

-

Uluslararası bilimsel toplantılarda sunulan ve bildiri kitabında (*Proceedings*) basılan bildiriler

Journal of Exercise Therapy and Rehabilitation, A Yagcioglu, F Subasi Yoga Egzersizlerinin Non-spesifik Kas İskelet Ağrısı Üzerine Etkisi, 9. Uluslararası Spor Fizyoterapistleri Kongresi, Ankara, 2017
Journal of Exercise Therapy and Rehabilitation, A Yagcioglu, R Kurtulmuş, SN Çimen, M Erdem, M Selami, Kalf Kası Üzerine Kinezyoteyp Uygulamasının Sıçrama ve Denge Üzerine Anlık Etkisi, 9. Uluslararası Spor Fizyoterapistleri Kongresi, Ankara, 2017

European Respiratory Journal, Develi, E., Aytutuldu, G. K., Yagcioglu, A., Pekdas, M. A., Muammer, R., & Ozdincler, A., The immediate effects of core stabilization exercise on pulmonary parameters, ERS International Congress, Paris, 2018

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar

39. Ulusal Solunum Kongresi, A Yağcıoğlu, E Develi, GK Aytutuldu, F Subaşı, Düzenli Aerobik Egzersiz Yapan Veya Yoga Eğitimi Alan Bireylerin Dinamik Denge Ve Solunum Parametrelerinin Karşılaştırılması, İzmir, 2017
7. Egzersiz Fizyolojisi Sempozyumu, B Celbek, A Yağcıoğlu, Ş Dinçer, M Altan, M Mengi, G Metin, 15-16 Yaş Arası Basketbolcularda Farklı Egzersiz Şekillerinin Aerobik Ve Anaerobik Kapasiteye Etkisi, Eskişehir, 2019

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)

Fonksiyonel Bantlama Kursu, Acıbadem Sports, İstanbul, 2016
Myofasyal Gevşetme Teknikleri, Spor Fizyoterapistleri Derneği, Ankara, 2016
39. Ulusal Solunum Kongresi, 2017, İzmir. Kongre Katılım Bursu.
Solunum Sisteminin Fonksiyonel Değerlendirilmesi, Türkiye Solunum Araştırmaları Derneği, İzmir, 2017
Ağrı, Nöroplastisite ve Egzersiz, Fizyodemi, Yeditepe Üniversitesi, 2019
Kronik Ağrıda Manuel Terapi ve Egzersiz, Fizyodemi, Yeditepe Üniversitesi, İstanbul, 2019
Lumbal Bölge Patolojilerinde Tedavi Yöntemleri, İstanbul, 2019