T.C.

YEDİTEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

MASTER'S PROGRAM IN SPORTS PHYSIOTHERAPY

THE EFFECT OF NEUROMUSCULAR AND VESTIBULO-OCULAR REFLEX TRAINING PROGRAM ON BALANCE, ISOKINETIC MUSCLE STRENGTH AND PROPRIOCEPTION IN SUBJECTS WITH CHRONIC ANKLE INSTABILITY

Master Thesis

Nilüfer KILIÇ CERBEZER, PT

İSTANBUL – 2022

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Nilüfer KILIÇ CERBEZER, PT

ADVISER
Prof.Dr.Feryal SUBAŞI,PT

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This study have approved as a Master Thesis in regard to content and quality by the Jury.

	Title, Name-Surname (Institution)
Chair of the Jury:	Prof.Dr.Feryal SUBAŞI Yeditepe University
Supervisor:	Prof.Dr.Feryal SUBAŞI Yeditepe University
Member/Examiner:	Dr.Öğr.Üyesi Anıl TEKEOĞLU TOSUN Fenerbahçe University
Member/Examiner:	Dr.Öğr.Üyesi Elif ÜSTÜN DEVELİ Yeditepe University

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 … and numbered….

Prof. Dr. Bayram YILMAZ
Director of Institute of Health Sciences

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 acknowledgment has been made in the text.

04.02.2022

Nilüfer KILIÇ CERBEZER

DEDICATION

This thesis is dedicated to my parents who have given me the opportunity of an education from the best institutions of Yeditepe. Thank you for always supporting me.I also thank everyone who contributed on me.

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LIST OF SYMBOLS AND ABBREVIATIONS

CAI	Chronic Ankle Instability
VR	Vestibular Rehabilitation
VRT	Vestibular Rehabilitation Training
PTFL	Posterior Talofibular Ligament
ATFL	Anterior Talofibular Ligament
CFL	Calcaneofibular Ligament
FA	Fibular Artery
ATA	Anterior Tibial Artery
ALMA	Anterior Lateral Malleolar Artery
PMMA	Posterior Medial Malleolar Artery
DPA	Dorsalis Pedis Artery
MPA	Medial Plantar Artery
LPA	Lateral Plantar Artery
LTA	Lateral Tarsal Artery
ROM	Range of Motion
FI	Functional Instability
MI	Mechanical Instability
MRI	Magnetic Resonance Imaging
US	Ultrasonography
CT	Computed Tomography
FADI	Foot and Ankle Disability Index
FAAM-ADL	Foot and Ankle Ability Measure Activity of Daily Living
FAAM-S	Foot and Ankle Ability Measure Sport
SEBT	Star Excursion Balance Test
STJN	Subtalar Joint is in Neutral Position
SPSS	Statistical Package for Social Science
BMI	Body Mass Index
NG	Neuromuscular Group

VOG	Vestibulo-ocular Group
PM	Postreomedial
AM	Anteromedial
AL	Anterolateral
PL	Posterolateral
E	Eversion
I	Inversion
CNS	Central Nervous System
DVA	Dynamic Visual Acuity
GS	Gaze Stability

ABSTRACT

KILIÇ, N. (2022). The Effect of Neuromuscular and Vestibulo-Ocular Reflex Training Program on Balance, Isokinetic Muscle Strength and Proprioception in Subjects with Chronic Ankle Instability. Yeditepe University, Institute of Health Sciences, Department of Sport Physiotherapy,Master Thesis. Istanbul.

The aim of the study is to compare the effects of neromuscular exercise combined with vestibulo-ocular reflex training on balance,isokinetic muscle strength and proprioception in subjects who have ankle instability. This study was conducted in Sportomed Athlete Health and Orthopedic Rehabilitation clinic in February 2020, September 2022.A total of 20 participants aged 18-30 were included in the study on a voluntary basis. Participants were divided into two groups at random. Demographic information and informed consent forms were filled into all subjects who volunteered to participate in the study and in accordance with the research criteria. After the evaluation, the subjects in the first group were included in the vestibulo-ocular exercise program in addition to the neuromuscular exercise programs with the same physiotherapist. Subjects in the second group were included in neuromuscular training programs. The trainings were applied three days a week for four weeks and each training session lasted approximately 60 minutes. Functional limitations of the participants before and after the treatment were evaluated with the Foot and Ankle Ability Measure Daily Living Subscale (FAAM-ADL) and Sports Subscale (FAAM-S). Dynamic balance evaluation with star excursion balance test, proprioception evaluation by measuring joint position sense with goniometer, and ankle evertor and inverter concentric muscle strength were evaluated using isokinetic dynamometer at angular velocities of 60/s, 120/s and 180/s, and the results were recorded. According to statistical analysis,significant changes were observed in balance, muscle strength and proprioception before and after treatment in both groups ($p<0.05$).However, no superiority was found between the two treatment groups ($p<0.05$).In conclusion, it is suggested that neuromuscular training and vestibulo-ocular training have positive effects on balance, muscle strength and proprioception, and neuromuscular and vestibular training should be included in chronic ankle treatment.

Key Words: ankle instability, balance, neuromuscular,vestibulo-ocular,training,strength

ÖZET

KILIÇ, N. (2022). Kronik Ayak Bileği İnstabilitesi Olan Kişilerde Nöromüsküler ve Vestibulo-Oküler Refleks Antrenman Programının Denge, İzokinetik Kas Kuvveti ve Propriosepsiyon Üzerine Etkisi Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Spor Fizyoterapisi Yüksek Lisans Tezi, İstanbul.

Bu çalışmanın amacı,kronik ayak bileği instabilitesi olan kişilerde vestibulo-oküler refleks eğitimi ile kombine neromusküler egzersizin denge,izokinetik kas kuvveti ve propriosepsiyon üzerindeki etkilerini karşılaştırmaktır. Çalışmaya 18-30 yaş arası toplam 20 katılımcı gönüllülük esansına göre dahil edildi. Bu çalışma Sportomed Sporcu Sağlığı ve Ortopedik Rehabilitasyon kliniğinde Şubat 2020- Eylül 2021 tarihinde yapıldı.Katılımcılar rastgele 2 gruba ayrıldı.Araştırmaya katılmaya gönüllü olan tüm olgulara araştırma kriterlerine uygun olarak demografik bilgiler ve aydınlatılmış onam formları dolduruldu. Değerlendirme sonrasında birinci gruptaki denekler aynı fizyoterapist ile nöromüsküler egzersiz programlarına ek olarak vestibülo-oküler egzersiz programına dahil edildi.İkinci gruptaki denekler nöromuskuler egzersiz eğitimine dahil edildi. Eğitimler 4 hafta boyunca haftada üç gün uygulandı ve her bir eğitim seansı yaklaşık 60 dakika sürdü.Katılımcıların tedavi öncesi ve sonrası fonksiyonel kısıtlılıkları Ayak ve Ayak Bileği Kullanılabilirlik Ölçüsü Günlük Yaşam Alt Ölçeği (FAAM-ADL) ve Spor Alt Ölçeği (FAAM-S) ile değerlendirildi. Yıldız denge testi ile dinamik denge değerlendirmesi, gonyometre ile eklem pozisyon duyusu ölçülerek propriosepsiyon değerlendirmesi ve ayak bileği evertor ve invertör konsantrik kas kuvveti izokinetik dinamometre kullanılarak 60/s, 120/s ve 180/s açısal hızlarda değerlendirildi ve sonuçlar kaydedildi. İstatistiksel analizlere göre her iki grupta da tedavi öncesi ve sonrasında denge, kas gücü ve propriosepsiyonda önemli değişiklikler gözlendi ($p<0.05$). Ancak, iki tedavi grubu arasında bir üstünlük bulunamadı ($p>0.05$). Sonuç olarak, nöromüsküler eğitim ve vestibülo-oküler eğitimin denge, kas kuvveti ve propriosepsiyon üzerine olumlu etkilerinin olduğu, kronik ayak bileği tedavisine nöromüsküler ve vestibüler eğitimin dahil edilmesi gerektiği önerilmektedir.

Anahtar Kelimeler: ayak bileği instabilitesi, denge, nöromüsküler, vestibülo-oküler eğitim,kuvvet

1.INTRODUCTION

Ankle sprains, particularly injuries to the lateral ligament group of the ankle joint, are among the most common lower extremity injuries in athletes [1].The prevalence of CAI expected between %40 and 70% in the individuals having an acute ankle instability after first lateral ankle sprain history due to recurrences. The prevalence of CAI seems to be higher among the athletes such as basketball player, runner, volleyball player [2].

Varus mal alignment of the lower extremities has been identified as a significant risk factor for ankle sprains and CAI. Anatomical variations such as the axis of rotation, the talar dome radius, or the retroposition of the lateral malleolus can be precursor to the ankle sprain and CAI. Pathological conditions of the tibiotalar joint, such as limitation of dorsiflexion (anterior compression, shortgastrocnemius), chondral problems or bimalleolar diastasis, subtalar joint laxity may increase CAI. Anatomical and histological variations of collateral lateral ligament are very important internal risk factors for CAI. Pathologies of the peroneal tendon can induce or exacerbate CAI, and pathologies including a proprioceptive deficit or an imbalance in neuromuscular control are a typical cause of CAI. The most prevalent symptoms of CAI include giving way of the ankle, mechanical imbalance, pain and swelling, loss of strength, recurrent sprains, and functional imbalance [3].

Conservative CAI treatment is widely considered as the primary method of managing the condition and preventing re-injury. Following rehabilitation programs, improvements in proprioception and neuromuscular control have been demonstrated [4]. Clinical intervention for people who have had recurrent ankle sprains usually consists of therapeutic exercise protocols that address specific deficits, such as range of motion, balance, strength, and functional training [5].

Balance training has often been used in the rehabilitation of CAI patients for a long time.Balance training usually entails the progression of the balance of the single leg, which adds perturbations that include removing visual input, changing the surface, or adding tasks such as throwing the ball or achieving tasks. More difficult tasks, such as jumping, can be included in dynamic balance [5].

Ankle instability can be treated and prevented with neuromuscular training. Neuromuscular training aims to increase functional joint stability and thus protect against injury by improving neuromuscular control. Strengthening, stretching, plyometric, and balance exercises are usually included in these programs [6]. Neuromuscular training is defined as training that stimulates both afferent signals and central systems responsible for dynamic joint control to increase unconscious motor functions [7]. The described neuromuscular training approach uses biomechanical and neuromuscular concepts to promote sensorimotor control and compensatory functional stability.

The training or retraining of the vestibulo-ocular reflex [6] is an Vestibular rehabilitation (VR) is a well-known exercise program aimed at resolving balance disruption caused by peripheral vestibular system damage [7]. By using head eye movement, vision substitution, somatosensory cues, and postural methods, VRT facilitates vestibular healing processes and adaptability.The purpose of VRT is to improve gaze stability, postural stability, and daily tasks.The basic exercises for VRT are to maintain balance with a reduced base of support with various aspects of the head and body, performing various body postures and activities, head-eye movements,various upper extremity tasks and general strengthening and flexibility exercises [8].

The aim of the study is to compare the effects of neromuscular exercise combined with vestibulo-ocular reflex training on balance and isokinetic muscle strength in subjects with chronic ankle instability.

Hypotheses of the study;

H0: Vestibulo-ocular reflex training protocol, which is given in addition to the neuromuscular exercise program, has an effect on isokinetic ankle muscle strength and balance in individuals with ankle instability.

H1: Vestibulo-ocular reflex training protocol, which is given in addition to the neuromuscular exercise program, has no effect on isokinetic ankle muscle strength and balance in individuals with ankle instability.

2.GENERAL INFORMATION

2.1. Ankle and Foot Anatomy

The ankle joint is among the most often injured joints and complex structures in the musculoskeletal system. The ankle joint is a type of synovial modified uniaxial hinge joint. [9].

Ankle; transmits the forces from the lower limbs to the feet and the reaction forces from the ground to the upper segments [10].

The foot and ankle complex composed of tibia, fibula and 26 irregular foot bones, 30 synovial joints and over 100 ligaments [11]. Seven of the foot bones are tarsal, five are metatarsal and 14 are phalangeal bones. Tarsal bones; They are called talus, calcaneus, navicular, cuboid and cuneiform (1-3). Talus-calcaneus hindfoot, navicula, cuboid, 3 cuneiform midfoot, and metatarsals and phalanxes also form the forefoot [12].

The tibia is the main bone that carries the load between the femur and talus and supports the joint medially with the medial malleol. The fibula carries 7% of the load in the neutral position and supports the joint laterally with the lateral malleol [12].

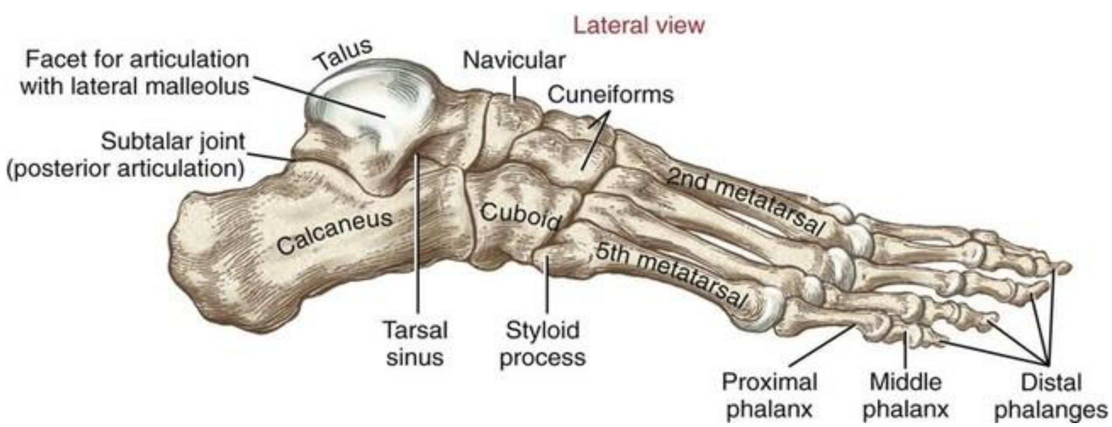


Figure 2.1. A view of the bones of the right ankle and foot from the lateral [13].

The ankle consists of three joints: the talocrural joint, subtalar joint, and distal tibiofibular syndesmosis. These three joints cooperate to provide for coordinated rearfoot movement.

Sagittal plane motion (plantar flexion-dorsiflexion), frontal plane motion (inversion), and transverse plane motion (internal rotation-external rotation) are the most common rearfoot movements [14].

2.1.1.Talocrural Joint

It consists of the superior aspect of the talus, the distal portion of the tibia, and the medial and lateral malleoli. When viewed on its own, the rotational axis of this joint goes through the malleoli, allowing plantar flexion and dorsiflexion by allowing the joint to be considered a hinge joint. [15].

The articular surfaces of the tachloral joint are the principal stabilizer against excessive talus rotation and translation when the ankle is loaded. In addition, the talocrural joint is stabilized by the integration of various ligaments, joint capsule and musculotendinous units [14].

Anterior talofibular ligament, posterior talofibular ligament (PTFL), calcanofibular ligament (CFL), and deltoid ligament support the talocrural joint. The lateral side of the ankle is supported by the ATFL, PTFL, and CFL, whereas the medial side is supported by the deltoid ligament. [15].

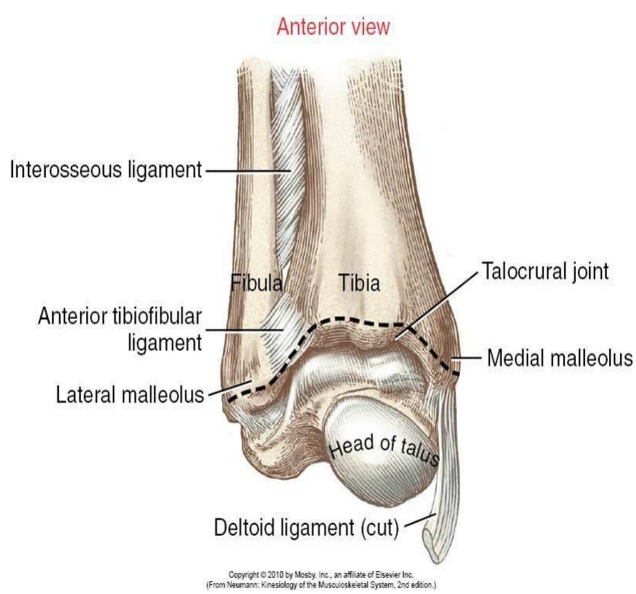


Figure 2.2. Anterior View of Ankle and Talocrural Joint [13].

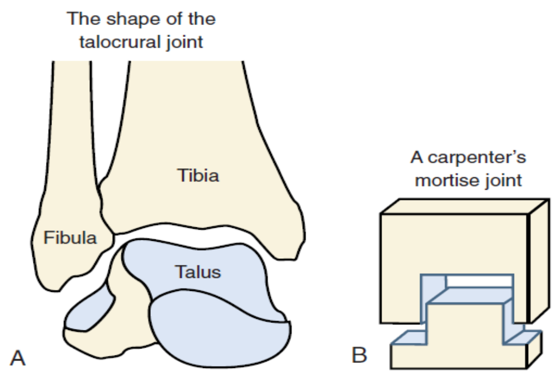


Figure 2.3. The talocrural joint **(A)** and that of a carpenter's mortise joint **(B)** [13].

2.1.2.Subtalar Joint

The subtalar joint is created by articulation between the talus and calcaneus and, like the talocrural joint, rotates the torque between the lower leg (inner and outer rotation) and the foot (pronation and supination). Subtalar joints have two independent joint areas that allow for pronation and supination movements [14].

The posterior subtalar joint is created by the talus's lower posterior joint face and the calcaneus's upper posterior joint face.The head of the talus, anterior-superior facets, the secondary sustentaculum, and the tarsal navicular surface of the calcaneus form the anterior subtalar joint.The talus head is ball-shaped, and the anterior surface of the calcaneal and proximal navicular surfaces form the socket, similarly to a ball and socket joint [14].

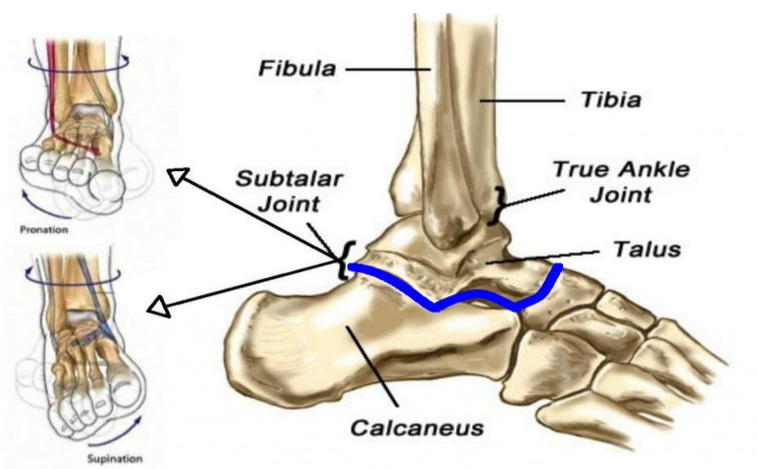


Figure 2.4. Lateral view of Ankle Subtalar Joint [16].

2.1.3.Distal Tibiofibular Syndesmosis Joint

Distal Tibiofibular Syndesmos occurs between the fibula and the distal articular surfaces of the tibia. It is surrounded by connective tissue, the directions of which are irregular.Since Syndesmosis type is a joint, it has limited sliding motion [17,18]. Although the interosseous membrane is the major stabilizer for this joint, the posterior and inferior tibiofibular ligaments, which are frequently affected during eversion ankle injuries, provide additional support [15,19].

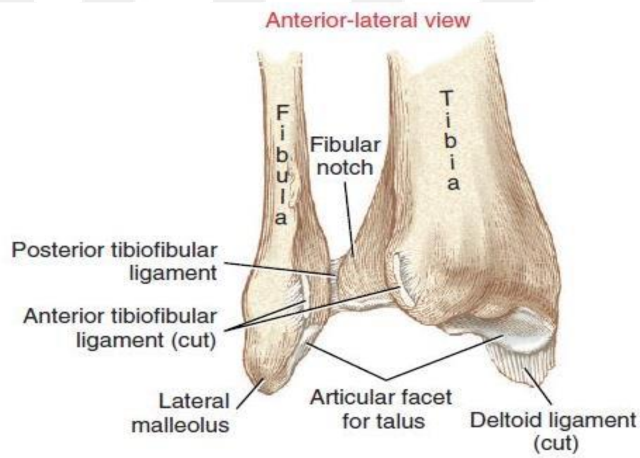


Figure 2.5. An anterior view of the talus and the distal end of the right tibia and fibula [13].

2.1.4.Talocalcaneonavicular Joint

The talus, calcaneus, and navicular bones constitute the tallocalcaneonavicular joint.It is a plana type joint, it is important for the ankle as it moves together with the subtalar joint. The joint has an oblique axis that travels from top to bottom, from inside to outside, from front to back. Adduction with supination and abduction with pronation occurs on the foot around this axis [18,20].

2.1.5.Calcaneocuboideal Joint

The anterior of the calcaneus and the posterior surface of the cuboid bone form synovial joint. The bifurcated ligament on the top stabilizes it. [21].

2.1.6.Middle Foot Joints

It consists of joints occurring between the three cuneiform bones with the navicula, cuboid with the 3rd cuneiform, 2nd- 3rd metatarsal bones with the 3rd cuneiform, 1st metatarsal bone with the medial cuneiform, 4th-5th metatarsal bones with the cuboid [17].

2.1.7.Metatarsophalangeal Joints

Heads of metatarsal bones and bases of proximal phalanges form these synovial joints. Plantar and collateral ligaments provide support. They allow toes to flex and extend, and to separate them closer together [21].

2.1.8.Interphalangeal Joints

The phalanges are connected by these joints.They are synovial joints that are supported by collateral and plantar ligaments and allow the toes to flex and extend [21].

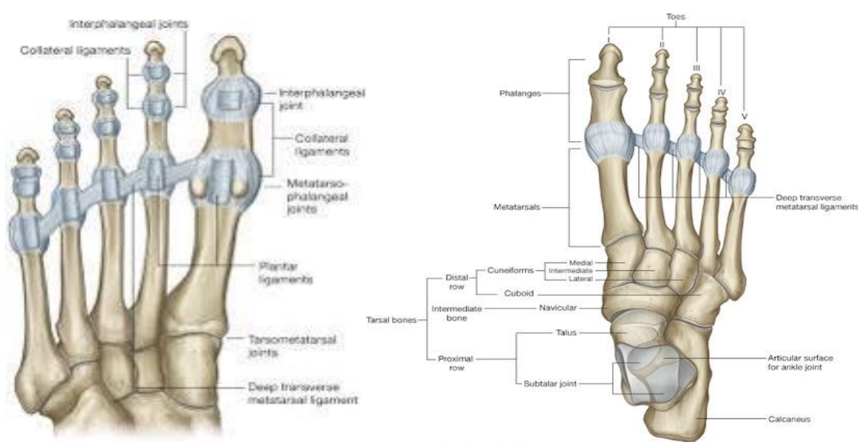


Figure 2.6. Interphalangeal Joints [22].

2.1.9.Ankle Ligaments

There are three groups of ligament complexes, namely medial collateral, lateral colleteral and synodic ligament complex, which support the ankle joint and stabilize it [22].

2.1.9.1.Medial (deltoid) ligament of the ankle: The medial malleolus is connected by this strong ligament. It is divided into four sections: tibionavicular, tibiocalcaneal, anterior tibiotalar, and posterior tibiotalar [21]. The main task of the group is to restrict eversion [17].

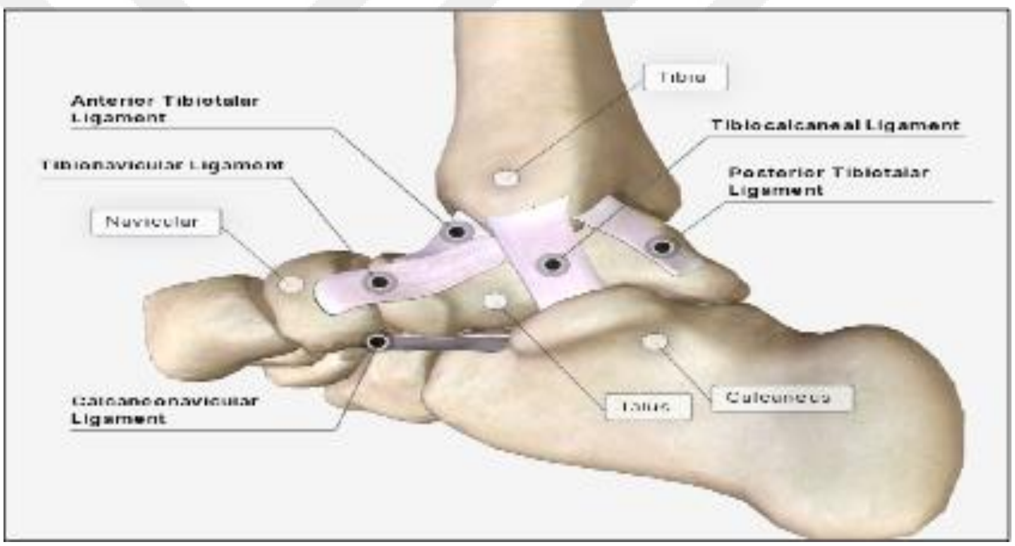


Figure 2.7. Ligaments Supporting the Medial Part of the Ankle (Deltoid Ligaments) [23].

2.1.9.2.Lateral ligament of the ankle: It consists of three bands that begin at the lateral malleolus:

2.1.9.2.1.Anterior talofibular ligament: It extends to the talus's lateral surface.

2.1.9.2.2Calcaneofibular ligament: It extends to the calcaneus's lateral surface.

2.1.9.2.3.Posterior talofibular ligament: This ligament attaches to the talus's lateral tubercle [21]. When the lateral ligaments are compared in terms of strength, ATFL is the weakest ligament in them. CFL is 2.5 times and PTFL is 2 times stronger than ATFL [24] .In other words, CFL is the strongest among them [17].

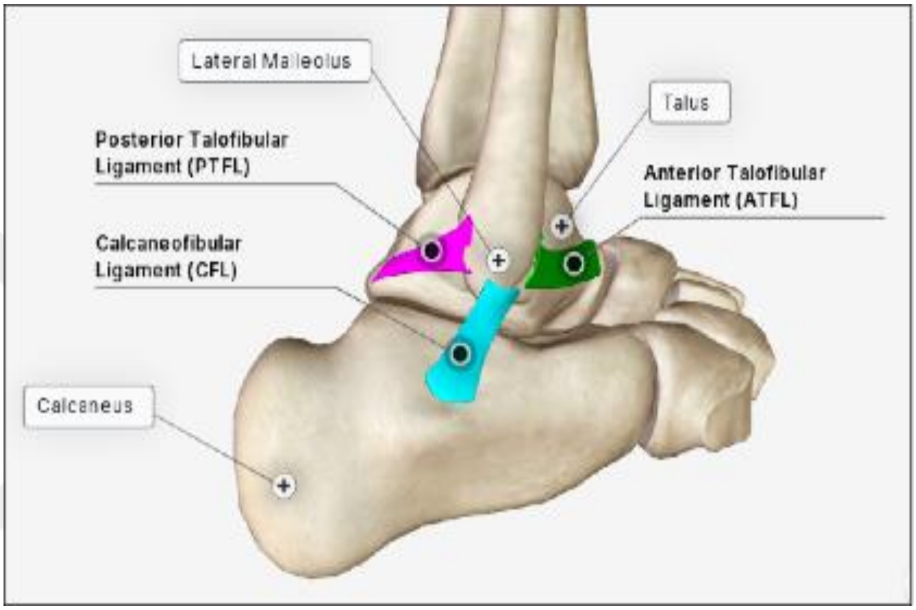


Figure 2.8. Ankle Lateral Ligaments [23].

2.1.9.5.Syndesmosis Ligament

The syndesmosis ligament complex is placed between the distal tibia and fibula and is responsible for ensuring integrity against rotational, axial and translational forces in this region. The syndesmosis ligament complex consists of four parts [22].

- Lig. Tibiofibulare Anterior
- Lig. Tibiofibulare Posterior
- Lig. Interosseous Membran
- Lig.İnferior Transvers

2.1.10.Ankle Muscles

There are three compartments in the leg: anterior, lateral, and posterior.These compartments' muscles aid in the movement of the ankle and foot. The anterior compartment muscles arise from the anterior surfaces of the tibia and fibula, the anterior peroneal intermuscular septum, and attach to the medial plantar portions of the first cuneiform and first metatarsal [25].The anterior muscles make dorsiflexion to the ankle and extension to the toes. The deep fibular (peroneal) nerve innervates (provides nerve supply) these muscles. Fibularis brevis and fibularis longus are the two muscles that make up the lateral compartment. They originate on the fibula's lateral surface [21]. The peroneus longus muscle crosses the plantar portion of the foot, inserting the first metatarsal base and medial cuneiform. The superficial fibular (peroneal) nerve innervates them, which helps the foot plantarflex and evert [21]. There are two types of muscles in posterior group: superficial and deep. The gastrocnemius and soleus are part of the superficial group. The deep muscle group includes the popliteus, tibialis posterior, flexor hallucis longus, and flexor digitorum longus [17,18].

Calcaneal tendon, which inserts into the back of the calcaneus, connects the following superficial muscles that plantarlex the ankle [21] .They are innervated by the tibial nerve [17].

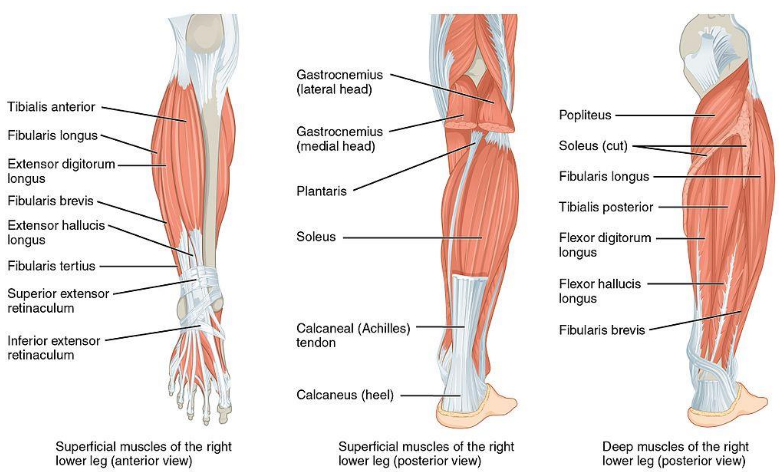


Figure 2.9. Anterior and posterior compartments of lower leg muscles [26].

2.1.11.Sensory Innervation of the Ankle

The ankle is an organ with prominent sensory innervation rather than fine motor skills like a wrist. It also includes a large innervation area in the sensory cortex. There are five main nerves in the ankle: saphenous, tibial, sural, peroneus superficialis, peroneus profundus.
The femoral nerve's terminal sensory branch is known as the saphenous. It wraps around the medial malleolus and extends medially and ventrally to the joint capsule, extending from the medial to the distal end of the tibia.The tibial nerve innervates the dorsal periosteum of the tibia and the medial and dorsal of the ankle joint capsule.The sural nerve is formed by peroneus cominus and one branch from the tibial nerve. It innervates the lateral side of the heel, fibula periosteum, talofibular and talocalcaneal joints.Peronealis superficialis innervates the periosteum of the tibia and fibula and the ventral of the tibiofibular joint.Peronealis profundus innervates the ventral and lateral of the tibia periosteum, syndesmosis, tibiofibular joint capsule and cranial ankle [27].

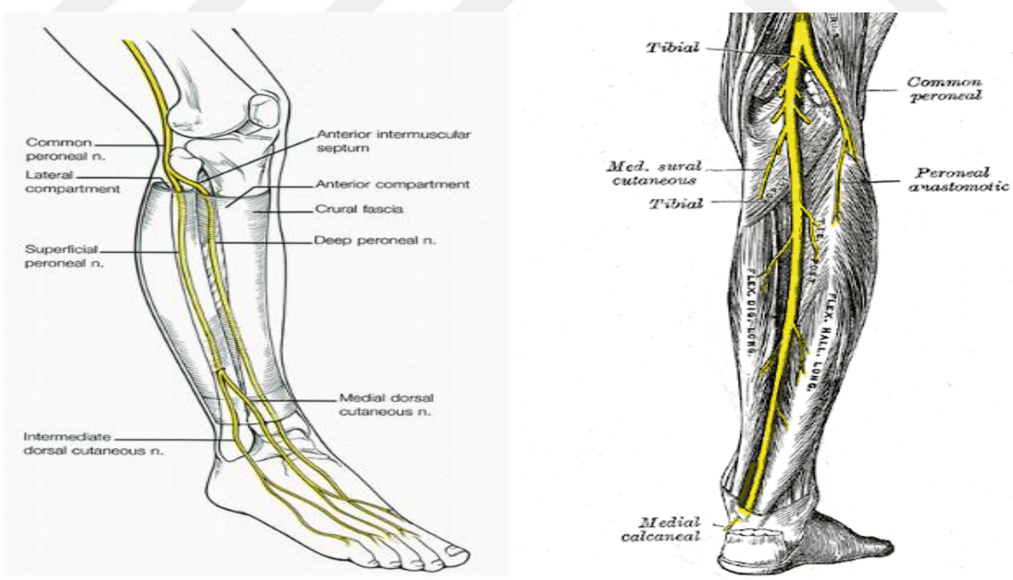


Figure 2.10. The superficial peroneal nerve pierces the crural fascia and gives off two branches to supply sensation to the dorsal aspect of the ankle and foot [28].

2.1.12.Vascular Supply to Ankle and Foot

The primary artery of the ankle and foot is the anterior tibial artery, whereas the main artery of the posterior and lateral compartments is the posterior tibial artery.These two arteries originate at the posterior knee, where the popliteal artery is divided, and feed the three compartments as well as sending the terminal branches into the foot [21].

2.1.12.1.Anterior Tibial Artery: It originates from the popliteal artery and passes between the tibialis anterior and extensor digitorum longus muscles. [21].

2.1.12.2.Posterior Tibial Artery: It originates in the poplitea artery and goes through the posterior part of the leg, into the flexor retinaculum, and in the sole of the foot. [21].

2.1.12.3.Fibular Artery: It is a proximal posterior artery branch. It also goes behind the fibula in the posterior compartment of the leg.It has perforating branches that feed the lateral compartment and supplies the posterior compartment of the leg. [21].

2.1.12.4.Dorsal Pedis Artery: It goes along the dorsum of the foot, branching off from the anterior tibial artery. It passes as a deep plantar artery and runs from the first dorsal interosseous muscle to the sole of the foot where the lateral plantar artery joins to form the plantar arch (deep plantar arch) [21].

2.1.12.5.Deep Plantar Artery: The plantar arch is formed by this artery running along the sole of the foot and connecting with the lateral plantar artery [21].

2.1.12.6.Metatarsal Arteries: They enter the slits between the toes and the branch, nourishing the toes' digital arteries [21].

2.1.12.7.Lateral Plantar Artery: It is a part of the posterior tibial artery and runs along the sole of the foot [21].

2.1.12.8.Medial Plantar Artery: It's a tibial artery branch. It's on the medial side of the foot's sole [21].

2.1.12.9.Plantar Metatarsal Arteries: It is a branch of the deep plantar arc that supply blood to the foot's sole [21].

Veins are divided into two as deep and superficial veins. Deep veins consist of veins with a many of valves that accompany the arteries. Superficial small veins combine to form vena saphena parva and magna [18,20].

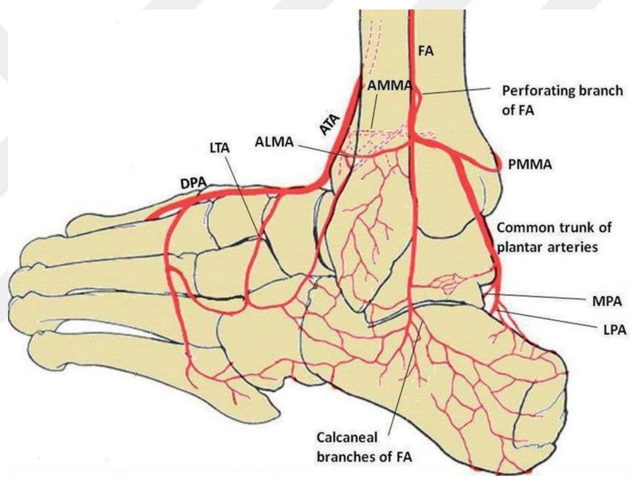


Figure 2.11. The fibular artery (FA) branching pattern and anastomosis with the anterior tibial artery (ATA) [29].

2.1.13.Ankle Biomechanics

Foot and ankle provide the connection of the human body with the ground and it is a dynamic structure. Although lower extremity joints and structures are handled and evaluated separately, when examined functionally, all lower limb, foot and ankle joints are functionally in harmony. The ankle joint cannot be evaluated biomechanically as a single structure alone, because the ankle is directly related to other parts of the lower limb and concerns the whole body. In order for the foot and ankle joint to work most effectively and efficiently by consuming minimum energy, it must work in harmony with other lower limb joints.It is one of the most important duties of the foot to carry the weight of the body and also to push the body forward and forward while running and walking. In addition, the ankle transfers the weight of the body from the lower extremity to the foot and ensures the compatibility of the foot with different floors [30].

The ankle has a moderately significant level of congruency, which means that even when exposed to stresses during everyday activities, the load-bearing surface of the ankle is large, resulting in less stress than the hip or knee [31]. Thanks to its ankle complex structure, it has the potential to carry weights much higher than the body weight. [30].

While the ankle is in contact with the ground, the foot acts as a closed kinetic chain and a weight-bearing function. In this phase, while the movement of the tibia and fibula is allowed, if the rotational forces in the femur are not absorbed in the knee, the force is reflected in the ankle bones [32].

The ankle serves as a rigid structure while providing stable support during posture during the post-push phase of the gait while providing stable support to maintain a smooth and upright posture without excessive muscle activation and energy expenditure. In addition, the ankle functions flexibly to provide shock absorption on different grounds and to be compatible with different grounds when in contact with the ground. Thanks to the ankle rotational movements, it adapts to different grounds and transmits its reaction forces from the ground to higher segments than itself [30].

The internal rotation of the tibia has been shown to result in the transmission of the movement along the ankle joint and its conversion into inversion in the subtalar joint. The transverse tarsal joint is locked by these rotations, resulting in a rigid longitudinal arch. The outward rotation of the tibia is transferred through the ankle and subtalar joints, resulting in calcaneus eversion and longitudinal arch unlocking, resulting in a flexible foot [33].

The rotation axis of the ankle joint, in other words its mechanical axis, goes through the lower end parts of the medial and lateral malleoli [34]. The ankle joint's axis is externally rotated from outside to inside by 20 ° -30 ° relative to the knee joint, but the foot is internally positioned relative to the ankle [33].In the coronal plane, there is an 80° (10°varus) angle between the longitudinal axis of the tibia and the axis of the ankle. This angle between these two axes ranges from approximately 68° to 88° [34]. Although the tibial plafond is parallel to the floor, the axis of the ankle joint diverges medially when measured from the malleoli ends. The articular surface of the talus is shaped like a cone with a medially oriented apex, rather than a cylinder. Although the apical angle is about 26 degrees, there is a significant variability. [33].

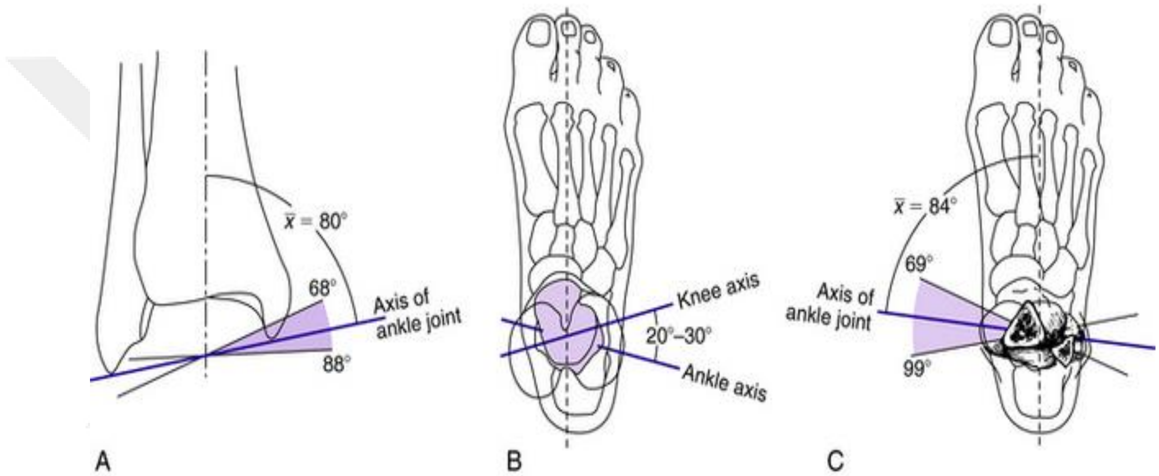


Figure 2.12. The tibia's long axis and the ankle joint form an angle. B, Relationship between the axes of the knee, ankle, and foot. C, Relationship between the ankle and the foot's longitudinal axis [35].

Plantar- and dorsiflexion in the sagittal plane; abduction and adduction in the transverse plane; and inversion-eversion in the frontal plane are the main movements of the ankle joint complex. Supination and pronation are three-dimensional motions that are created by combining these movements across both the subtalar and tibiotalar joints. Both terms refer to the position of the foot's plantar surface. While supination causes the sole to face medially due to a combination of plantar flexion, inversion, and adduction, pronation of the foot positions the sole laterally with a combination of dorsiflexion, eversion, and abduction [31]. Plantar and dorsiflexion movements of the ankle occur mainly at the tibiotalar joint in the sagittal plane.Several studies have shown that there is a general ROM in the sagittal plane between 65 and 75 degrees, ranging from 10 to 20 degrees of dorsiflexion to 40-55 degrees of plantarflexion. The total range of motion in the frontal plane is approximately 35 degrees

(23 degrees inversions and 12 degrees eversions).However, the ROM required in the sagittal plane in daily activities is greatly reduced by a maximum of 30 °for walking and 37 ° and 56 °for stair climbing and descending, respectively [31].

2.2.Ankle Ligament Injuries

Ankle sprains, particularly injuries to the lateral ligament complex of the ankle joint, are among the most common lower extremity injuries in sports populations [1].

Ankle sprains constitute approximately 30% of all sports injuries [36].When the general population is evaluated, the incidence of ankle sprain is approximately 1 / 10,000 per day [37].

Ankle soft tissue injuries are seen as 82.8% ATFL, 66.9% CFL, 34.2% PTFL injuries. Lateral ligaments are the most common injured ankle group [38].

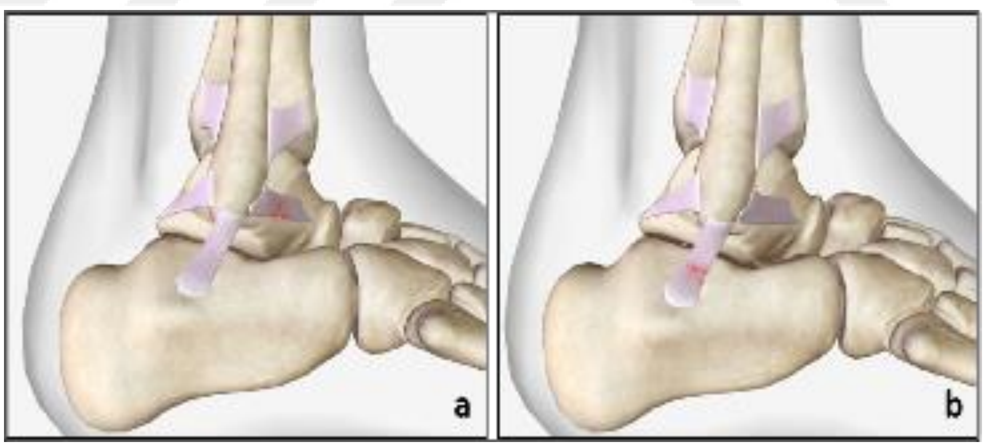


Figure 2.13. Partial Tears in ATFL and CFL after Lateral Ankle Sprain in the Direction of Inversion: (a) ATFL. (b) CFL. [23].

The ankle lateral ligaments are vulnerable to injury in the plantar flexion and inversion position, which causes the most stress on the anterotalofibular ligament (ATFL).Touching the ground in this position can lead to a large overreacting supination torque by increasing the moment arm of the reaction force [39]. When the foot is lifted and the floor or an object is unexpectedly met, the lateral ankle ligament complex can be injured. This can happen when running on an uneven surface, stepping into a gap, or landing on the foot of another athlete after a jump [40].

During an inversion injury, the ATFL is the most commonly torn ligament. Posterior talofibular and calcanofibular ligaments can also be injured if the force is large enough.The calcanofibular ligament is injured when the foot is dorsiflexed and inverted.Syndesmosis is commonly sprained by a dorsiflexion and an external rotation force is applied. A strong deltoid ligament is injured by an eversion / external rotation injury [40].
Since PTFL is anatomically located deep in the peroneal tendons, it is rare for isolated PTFL to be injured alone [38].In addition, compared to PTFL, ATFL and CFL, its shorter, thicker and stronger decreases the injury rate compared to others [42].
Deltoid ligament injury is rarer compared to lateral ligament injuries. The primary causes for this are that the lateral malleolus is longer than the medial malleolus, it meets excessive eversion, and this ligament group is stronger than the lateral ligaments [13].

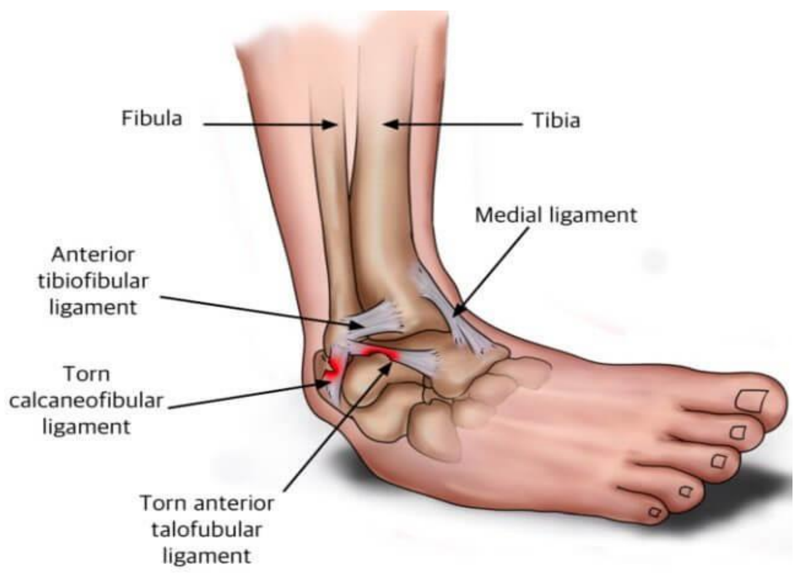


Figure 2.14. Inversion position is the main mechanism of lateral ankle sprains [43].

2.2.1.Classification

According to the severity of the injury, ankle lateral ligament injuries are classified as grade I (mild), grade II (moderate), or grade III (severe) in clinical practice.
Grade I injuries contain stretching the ligament without macroscopic rupture, minimal swelling or tenderness, minimal or no functional loss, and without mechanical joint instability.
Grade II is a partial ligament rupture that is tender to injury, moderate pain, swelling, and related structures. Mild to moderate joint instability and loss of joint movement are observed.
Grade III is a complete ligament rupture with injury,severe swelling, bleeding, and tenderness. Loss of function and pronounced abnormal joint motion and instability are observed [41].

2.3.Chronic Ankle Instability

Sequelae are very common after ankle ligament injuries. Chronic symptoms may occur in 10% to 30% of patients with lateral ligament injury [41]. The prevalence of CAI expected between %40 and 70% in the individuals having an acute ankle instability after first lateral ankle sprain history due to recurrences. The prevalence of CAI seems to be higher among the athletes such as basketball player,runner, volleyball player [44].

After first sprain within the six month, if the recurrence of ankle sprain seen and / or joint have giving way it would be considered as CAI [3].Symptoms generally contain permanent synovitis or tendinitis, ankle stiffness, swelling and pain, muscle weakness, and giving-way [41].

The CAI is used as an all-inclusive term to idenote the presence of both FI and MI. While the subjects had these symptoms, it is defined as functional instability (FI), mechanical instability (MI) is explained as an ankle movement that exceeds the physiological limit of the range of motion and also could clarify ankle laxity. MI of ankle joint refered increased in inversion laxity of hindfoot or excessive anterior talocrural excursion [45]. FI was characterized as joint movement beyond voluntary control but within normal physiological limits [46].

Mechanoreceptors joint capsule, ligaments, muscles and ankle it is located on the surrounding skin [47].The main reason for functional instability is the interruption of afferent impulses from these receptors to the central nervous system. Thus, reflex stabilization deficiency will occur [48].This event is described as giving way by people [48,14,49].

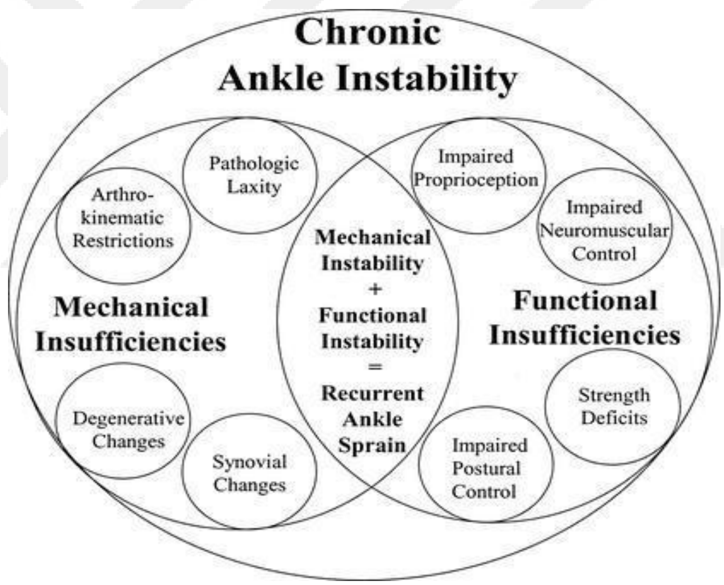


Figure 2.15. Factors causing Chronic Ankle Instability [14].

2.3.1.Risk Factors

In literature; the risk factors leading to CAI have been published and argued in lot of the studies.Varus mal-alignment of the lower extremities has been found as a significant risk factor for ankle sprain and CAI. In addition; anatomical variations such as the axis of rotation, the talar dome radius, or the retroposition of the lateral malleolus could be precursor to the ankle sprain and CAI. The tibiotalar joint has a variety of pathological conditions, such as restriction of dorsiflexion (anterior compression, short gastrocnemius), chondral problems or bimalleolar diastasis, may lead seeing CAI. Peroneal tendon pathologies can increase the possibilities CAI problem, and proprioceptive deficiency or imbalance in neuromuscular control are determined common reason of CAI. As a result, functional imbalance is caused by proprioceptive and muscle deficits following an ankle sprain [50].

2.3.1.1.Foot Characteristics

Morphological varieties of the foot and ankle complex might be related with CAI. With regard to calcaneus, an increased tendency of varus alignment has been identified in people with CAI [51].

In addition to the increased varus angle, people with CAI have a higher medial arc than people with a cavovarus foot type [52].

2.3.1.2.Pathological Laxity

Ligamentous damage of the ATFL, CFL, and deltoid often causes pathological laxity of the injured joints, and cause mechanical instability. The degree of pathological laxity of the ankle is related with the extent of damage to the lateral ankle ligaments. Pathological laxity can cause ankle joint instability in positions that can cause injury to structures during sports or functional activities. Pathological laxity can be evaluated by clinical examination, physical examination, stress radiography or instrumental arthrometry. Pathological laxity is usually found in the talocrural and subtalar joints after lateral ankle sprain [14].

2.3.1.3.Arthrokinematic Alterations

The presence of positional defects at the talocrural joint has been linked to CAI. A more anteriorly placed talus is associated with a decreased posterior glide associated with the tibia, which may limit dorsiflexion range of motion (ROM) at the talocrural joint. [53].

This reduced dorsiflexion ROM can prevent the ankle joint from reaching its functional closed packed position, which is is accepted to protect against accessory movement.Secondly, a more anteriorly placed fibula can be seen in the distal tibiofibular joint [54]. As a result, the anterior talofibular ligament is less stretched, allowing for more freedom talus movement [14].

After the ankle sprain and people with CAI, a more posteriorly placed fibula has been identified in relation to the medial malleol, which opens the talobrural joint mortise [55,56].

2.3.1.4.Impaired Proprioception and Sensation

The proprioceptive sense is the deep sense of the body, which is aware of the position and movements of the body and enables coordinated movements to be coordinated and the posture continues [17,18,57,58]. With the integration of the peripheral and central nervous system, the position and movements of the body parts and the whole are perceived.Michelson and Huttchins (1995) divided the proprioceptive sense voluntarily and reflexively. Voluntary proprioceptive sensation provides general control during sports and daily life activities, while involuntary (reflexive) proprioceptive sensation provides joint stabilization in unexpected situations. In severe acute ankle injuries involuntary proprioceptive sensation is more affected than voluntary proprioceptive sensation [59]. Afferent sensory transmission to the central nervous system about joint movement and position from the mechanoreceptors can be interrupted after injury. In this case, an imbalance may occur and FI may occur as a result [48].

2.3.1.5.Neuromuscular Control

Neuromuscular control can be described as the subconscious activation of dynamic constraints in the preparation and response necessary to maintain effective joint stability and regulate joint movement. [60]. Impairments in neuromuscular control may occur because of the changes in the forward and / or feedback mechanism [61]. The response times of peroneal muscles to inversion or supination perturbations are commonly used to demonstrate this. CAI patients have a slowed peroneal muscle reaction.This might be because of impaired proprioception, slowed nerve conduction velocity, or neuromuscular firing strategies.Recent research findings show bilateral impairments of recruitment of gluteus medius muscles in participants suffering from severe unilateral ankle sprain, so neuromuscular disorders indicate not only in injured ankle structures but also, but also in the neuromuscular pathways on the another limb, thereby demonstrating the central neural adaptations of the peripheral joints [14].

2.3.1.6.Postural Control

Postural control is defscribed as a person's ability to keep their center of mass on their base of support. This is dependent on the effective integration of afferent visual, vestibular, and somatosensory input to produce a sufficient efferent neuromuscular response [62].

Any of these deficiencies can result in a loss of postural control [63]. Many studies have shown that people with CAI have impaired postural control, [64,65] which is thought to be the result of a combination of proprioception and neuromuscular control deficits [14].

Neuromuscular control facilitates postural control and functional joint stability by providing dynamic constraints during joint movement and loading [60].Any injury that causes the mechano receptors damaging, changes in normal sensory input and processing of sensory information affects neuromuscular control. As a result, it may also cause injury or dysfunction in postural control, dynamic joint stability and functional ankle instability [66,67].

In order to assess postural control in people with CAI, researchers examined at both static and dynamic outcome measures. Dynamic postural control, defined as maintaining balance when changing from a dynamic to a static state, has been shown in studies to be more consistent in assigning postural control deficiencies in people with CAI [68].

The foot pronates and supinates to keep the body's center of gravity above the support base when in single-leg position.This is called the "ankle strategy". However, when compared to uninjured individuals, subjects with CAI appear to use a more "hip strategy" to maintain unilateral balance. To maintain the unilateral posture, the hip strategy is less effective than the ankle strategy. This change in postural control strategy is most likely the result of changes in central nervous control that occur when ankle joint dysfunction exists [14].

2.3.1.7.Strength

There are different opinions in the literature about the relationship between chronic ankle instability and muscle strength. The first is that the force decreases in the ankle evertor muscles. There are studies indicating that chronic ankle instability causes a decrease in evertor muscle strength [69,70] and that invertor muscle strength is higher than evertor muscle strength in subject with ankle sprain [71].

The second opinion is that the inversion movement cannot be controlled due to the lack of eccentric contraction mechanism of the evertor muscles [72].The activation of the peroneus longus muscle is lower in those with ankle instability in the fall-down activity on one leg stance after the jump [73].However, in individuals with unilateral CAI, there was no difference between the muscle strength measurements on the affected side and the measurements on the contralateral side, as a result of this, it is thought that there is a pre-existing condition or changes in central organization due to immobilization [69].

In a sudden inversion movement of the ankle, using the body correction mechanism, flexion on the same side knee and hip and adduction motion on the same side hip occur. Thanks to these movements, the angle of inversion of the ankle is reduced, the effect of the vertical ground reaction force is reduced [74]. Therefore, the strength of the hip and knee muscles is important for ankle injuries and instability.A hip-strengthening exercise program has been shown to reduce symptoms of chronic ankle instability and protect against recurrent sprains in people with chronic ankle instability [75]. In another study, women athletes with higher strength of the hip external rotator muscles have been shown to provide better dynamic control in the landing phase of the jump [76].

2.3.2.Symptoms

Giving way of the ankle, mechanical imbalance, pain and swelling, loss of strength, recurrent sprains, and functional imbalance are the most common CAI symptoms [77].

Because of the chronic symptoms of a previous ankle sprain, people who have chronic ankle instability have had to limit or change their daily activities or sporting interests. Combinations of stiffness, pain, swelling, 'giving way,' and instability were among the persistent symptoms reported in previous studies [78].

2.3.3.Assessments

History of the injury , mechanism of injury and past injuries, and observation and palpation, can give significant information about the anatomical structures that can be injured in a patient with ankle sprain [79].

Assessment of a patient with lateral ankle sprain should contain ecchymosis / bleeding, swelling, sensitivity, ankle range of motion, ligament laxity, strength, and general pain .Assessment of lateral ligament contains anterior drawer and talar tilt tests. These tests used to assess ligament stability, but do not show the desired diagnostic accuracy when performing isolated. [80].

Increased anterior -drawer motion may signal lenghtening or tearing of the ATFL. Increased inversion movement compared to a contralateral ankle suggests lengthening or tearing of CFL or, usually a combination of ATFL and CFL ruptures [42].

Inversion stress test can be done to evaluate ATFL and CFL by inversion of the hind foot in dorsiflexion and plantarflexion. Assesment of the peroneal muscles and tendons is an important to exclude another related pathology. Deltoid ligament and medial instability are tested by eversion stress test [39].

Although the diagnosis can be done clinically, determining all pathological conditions might be insufficient. Weight-bearing X-rays of both ankles are used to evaluate foot alignment and detect osteochondral lesions (OCL), avulsion fracture, periarticular changes, impingement, and osteoarthritis [39].

Magnetic resonance imaging (MRI) is a effective technique for detecting anterior talofibular ligament and calcanofibular ligament rupture [79].

Ultrasonography (US) is useful in assessing ankle ligaments because it produces a hyperechoic signal.US has an accuracy rate of up to 95% in acute ligament injuries, especially in ATFL ruptures, but an experienced operator is required to achieve these results.Computed tomography(CT) scan is not enough to diagnose ankle ligament pathology, but it is valuable to identify related pathologies [39].

2.3.4.Treatment and Prevention

ince CAI has a multi-factor basis, rehabilitation should address several deficiencies that may exist in patients with CAI. Therefore, adequate monitoring and evaluation of patients is the cornerstone of an effective rehabilitation. Traditional treatment methods generally focus on correcting ROM, increasing strength, correcting neuromuscular control and postural control [81].

While following rehabilitation programs, improvements in proprioception and neuromuscular control could be considered to prevent recurrences, the studies showed that proper rehabilitation protocols still needs to decrease the incidence the recurrence and manage the symptoms of CAI .

Chronic ankle sprains have been related to changes in joint movement.

There was an increase in anterior joint laxity, reduced posterior talar glide, and dorsiflexion range of motion deficit. An inversion mechanism caused by the positioning of the anterior talofibular ligament may result in anterior positional errors of the talus..Arthrokinematic movement disorders may be linked to these positional defects. Joint mobilization improves arthrokinematic movements by increasing dorsiflexion [5].

It is considered clinical practice to regain bilateral strength, which is important in preventing ligamentous injuries to the ankle [82]. Strength training can help to improve muscle spindle function and the ability to feel motion and force in the joint, which can help to compensate for the lateral ankle ligament fibers' mechanoreceptor deficiencies. Individuals with CAI may be able to detect and correct improper ankle posture due to improved muscular function, including joint position perception [83]. Exercises should concentrate on improving the condition of the peroneal muscles, as weakness in this group has been linked to CAI and recurrent injury [82].

Balance training has been used for a long time in the rehabilitation of patients with CAI. Balance training is hypothesized to successfully enhance the activation of mechanoreceptors, which increases sensory output, by stimulating the capsule and ligaments of the ankle, while gamma motor neurons are activated by this training [10].Balance training usually begins in a controlled environment on a stable surface, and progresses by introducing various perturbations to encourage the use of various sensorimotor systems. Balance training usually includes gradually progressing single-leg balance by introducing perturbations such as removing visual input, changing the surface, or adding tasks such as throwing the ball or completing tasks, all of which force the individual to adapt a balance strategy [4].

Taping and bracing are used to prevent ankle injuries from occurring and recurrence . Taping and bracing have been shown to prevent ankle injuries from basketball and football players,especially if an injury has been experienced before [84].

2.4.Neuromuscular Training

The term "neuromuscular training" refers to training that enhances unconscious motor responses by activating both afferent signals and the central systems that underlie dynamic joint control [85]. The described neuromuscular training method is based on biomechanical and neuromuscular principles, with the goal of improving sensorimotor control and achieving compensatory functional stability. Unlike traditional strength training, neuromuscular training focuses on movement quality and joint control in all three biomechanical / movement planes [86]. Neuromuscular training is important in the treatment and prevention of ankle instability.It is assumed that there is a predisposition to the development of ankle joint plantar flexion, ankle joint sprain, which is specifically increased at first contact with the ground during the jump landing.The results of the previous study show that the 6-week dynamic neuromuscular training program reduces ankle joint plantar flexion angle at the first contact during the jump landing [45].

Some research has shown that the neuromuscular rehabilitation program has an immediate impact on improving postural control and gaining eccentric evertor muscle strength and contributing to increased functional capacity to maintain strength [87].

Neuromuscular training aims to increase functional joint stability while also protecting against injury by improving neuromuscular control. Strengthening, stretching, plyometrics, and balance are all common components of these training programs [5].

2.5.Vestibulo-ocular Reflex Training

Training or retraining of the vestibulo-ocular reflex is an important component that is missing from most published ankle rehabilitation programs [6].Vestibular rehabilitation (VR) is a well-known exercise program aimed at eliminating the balance disruption caused by damage to the peripheral vestibular system [7].VRT facilitate vestibular healing mechanisms and vestibular adaptation, by the head eye movement,substitution with vision, somatosensory cues and postural strategies.The purpose of VRT are to increase gaze stability, increase postural stability,and increase activities of daily living. Maintaining balance with a reduced base of support while performing various head and body postures and activities, head-eye movements, various upper extremity tasks, and general strengthening and flexibility exercise are all examples of VRT exercises [8]. In previous studies, positive results of vestibular rehabilitation on postural stability have been shown [88]. Another study found that patients with vestibular exercise had a marked improvement in visual acuity during head movement (as measured by computerized tests), while those who did placebo exercises did not show significant improvement [89].

3.MATERIALS AND METHODS

This study was conducted in Sportomed Athlete's Health and Orthopedic Rehabilitation clinic to investigate the effects of two different training protocols on isokinetic muscle strength, balance and proprioception parameters in subjects with chronic ankle instability.

3.1.Subjects

A total of 20 patients between the ages of 18 and 30 were included in the study. Participants were included in the study on a voluntary basis. Each participants signed an informed consent form after the study's purpose and plan were explained to them.As for the first step, we separated the subjects according to simple randomization method.Participants were randomly seperated to 2 groups.

The estimated sample size for this study was calculated by changing the scores of the Foot and Ankle Disability Index [FADI] (FADI is the leader of FAAM) used by a similar study after four weeks of rehabilitation intervention (Hale, Hertel, Olmsted-Kramer, 2007). When these data are used, a total sample size of 20 subjects has been determined and had a power of 0.95 to detect differences in averages of 0.05. Type I error probability is 0.05. Subjects will be divided into two groups according to the randomized inclusion criteria.

3.1.1. Inclusion Criteria

Subjects were included;

- Being 18-30 years old
- Having had at least two previous lateral sprains of the same ankle
- Having had at least one episode of "giving way" within the previous 6 months
- Having persistent symptoms during functional activities and being free of symptoms from any previous lower extremity injuries
- No other injuries to the lower limbs

3.1.2. Exclusion Criteria

Subjects were excluded ;

- Having a bilateral ankle instability
- Having a history of ankle fracture
- Having a history of fracture or surgery to the involved lower extremity
- Having a history of balance and vestibular disorders

3.1.3. Flow of Research

Ethics committee approval required for this study was obtained from Marmara University Non-Interventional Ethics Committee with protocol number 21.Participants involveld in the study on a voluntary basis and written informed consent form was obtained from all subjcets who accepted the study (Appendix 1,2).

The study was started with 25 patients and a total of 20 patients completed the treatment program. The flow chart of the patients included in the study is shown in Figure 3.1.

The first group was received neuromuscular training with physiotherapist 3 times a week for 4 weeks. The second group was received vestibulo-ocular reflex training in addition to neuromuscular training accompanied by physiotherapist 3 times a week for 4 weeks.

Flow Chart of Research

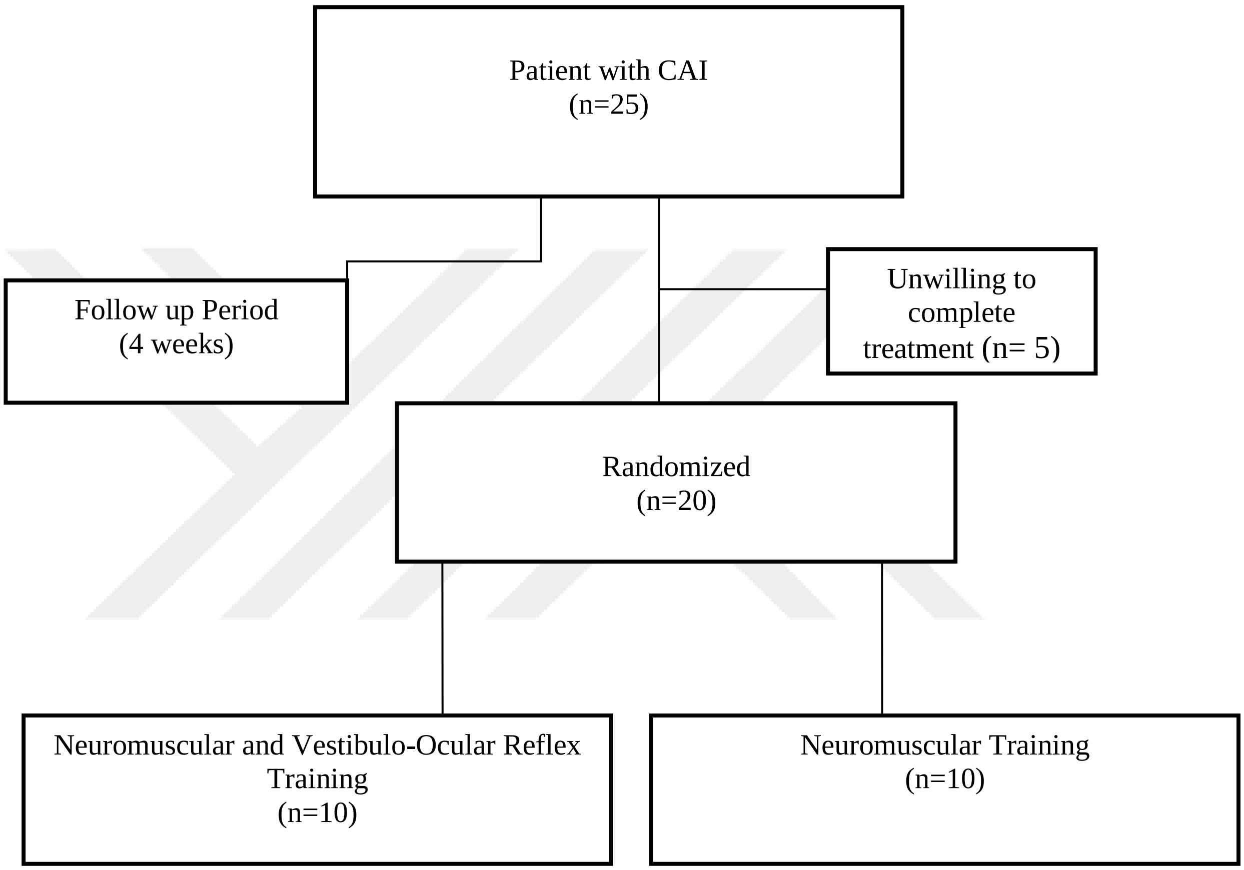


Figure 3.1. Flowchart Diagram

3.1.4. Study Protocol and Design

The purpose of the study and the content of exercise training programs were explained to all subjects according to the participant consent form. Demographic information and informed consent forms were filled in to all subjects who volunteered to participate in the study and in accordance with the research criteria. After the evaluation, the subjects in the first group were included in the vestibulo-ocular exercise program in addition to the neuromuscular exercise programs with the same physiotherapist 3 times a week for 4. The subjects in the second group continued their neuromuscular exercise programs for 4 weeks. Each training session took approximately 60 minutes. The neuromuscular included supervised, strength, balance and hop stabilization exercises on the different surfaces that focus on the restoring of static and dynamic balance. In the vestibulo- ocular exercise program, individuals tried to maintain their balance with head and eye movements in addition to the activities they did in neuromuscular exercise training.

3.2. Evaluation

Participants were evaluated before and after treatment and the results were recorded. Within the scope of the evaluation, the demographic information of the individuals was recorded. Measurements were made with a goniometer for the range of motion of the ankle joint. The strength of the ankle inverter and evertor muscles were measured concentrically with the Cybex Norm 2004 isokinetic dynamometer. In addition to muscle strength, star excursion balance test was used for dynamic balance and joint position sense test was used for ankle proprioception.

3.2.1.Demographic Information Form

The researchers made a face-to-face questionnaire that includes questions about age, gender, occupation, socio-demographic conditions, existing chronic diseases, previous surgical conditions and injuries, smoking and alcohol habits, and exercise behaviors.

3.2.2.Foot and Ankle Ability Measurement (FAAM)

Foot and Ankle Ability Measure (FAAM) is a scale developed to evaluate the physical functions of people who have foot and ankle disorders. It is a 29-item questionnaire divided into 2 subscales. These are the 21-item daily life subscale and the 8-item sports subscale. The sports subscale evaluates the more difficult tasks required for sports; a population-specific subscale developed for athletes. On a 5-point Likert scale, each item is rated from "no difficulty" to "unable to do" (from 0 to 4). The maximum score for the ADL subscale is 84 points, and the maximum score for the Sports subscale is 32 points. The maximum score is 84 points for the ADL subscale and 32 points for the Sports subscale, and the total score is converted to percentage points ranging from 0% to 100%. For both subscales, a higher score indicates a higher level of functionality.100% indicates that there are no malfunctions [90].

3.2.3.Range of Motion Measurement with Goniometer

In order to evaluate the ankle ROM of the subjects, all individuals were placed on a high ground where their feet could hang down. The pivot point of the goniometer was placed lateral malleolus for dorsiflexion and plantarflexion.The goniometer's fixed arm was held parallel to the lateral midline of the fibula. The movable arm of the goniometer was measured following the lateral midline of the 5th metatarsal bone.Measurement values were recorded [91].

Figure 3.2 Ankle Range of Motion Evaluation

3.2.4.Star Excursion Balance Test

Star Excursion Balance Test (SEBT) is a reliable measuring tool of dynamic balance. The test, designed to examine the injuries of the lower extremity, is also widely used for the determination of dynamic balance in sports. In addition, the SEBT test has been shown to have a high level of internal reliability coefficient, but its validity coefficients have not been studied. The test is a simple but time-consuming test and is used to measure dynamic postural balance [92].

SEBT is a closed kinetic chain study, so it requires sufficient strength, proprioceptive input, neuromuscular control and range of motion in the leg hip, knee, and ankle joint. For this test, participants stood at the center of an 8-line star-shaped device drawn at 45 degrees. Individuals were asked to reach anterior, anteromedial, medial posteromedial, posterior, posterolateral, lateral and anterolateral directions using one foot [93].Participants were taken barefoot to the test with the heel in the center and hands on the waist. Participants were asked to stand on a single leg posture on the test line, and to reach as far as possible with the opposite leg on the selected direction. The foot was only allowed to touch lightly, which did not help balance. Then the subject turned back to the starting position.The point where the subject touches was marked by the supervisor and is measured using a measuring tape.Subjects reached three times in each direction and the averages of the reach distances were recorded in centimeters. A 30-second break was made after each reach [94].

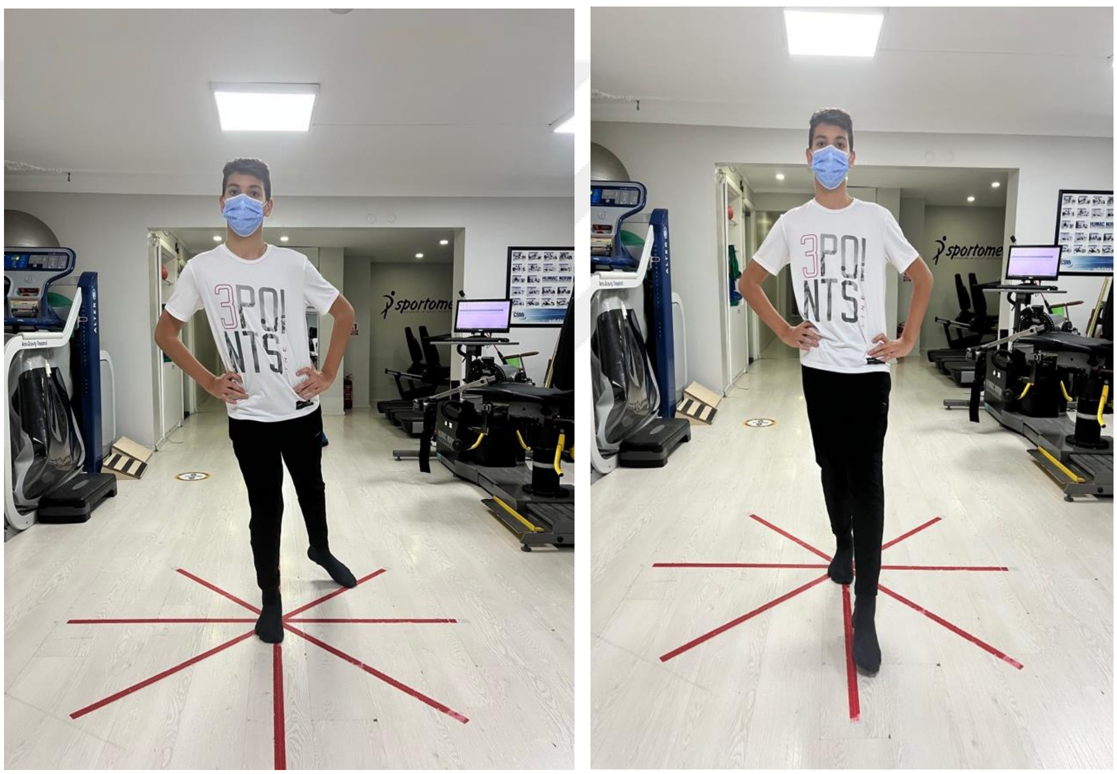


Figure 3.3. Star Excursion Balance Test

3.2.5.Isokinetic Muscle Strength

Test Protocol; The muscle strength of the ankle inverter and the invertor group before and after the treatment of all patients participating in the study was measured using CSMI Humac Norm 2004. Before the test, the patients were warmed on the bicycle ergometer at their own pace for 5 minutes. Individuals were informed about wearing sneakers before the test. Before each measurement, the device was calibrated. The knees and hip joints were seated in a 90 ° flexion position with a slope of 30 degrees and from the cruris region with knee velcro. The ankle was fixed to the dynamometer table in the neutral position, and the metatarsal bones were cross stabilized with the velcro at the level. As ankle test protocol, angular speeds of 60°/sec at slow speed, 120°/sec and 180°/sec at high speed were chosen. The individuals participating in the study were informed about the device and 3 replications of submaximal force were made before each angular velocity test. During the test, individuals were verbally and visually motivated for maximum force application. Concentric muscle strength (peak torque) of the invertor and evertor muscle groups at 3 angular velocities were evaluated. Firstly ,6 repetitions at low angular speed of 60°/s, followed by 6 rep at angular speed of 120°/s, finally 20 reps at high angular speed at 180°/s for endurance evaluation were done.Between each test, individuals were given a 10-second rest period [95].

Figure 3.4. Ankle Invertor and Evertor Muscle Isokinetic Strength Measurement

3.2.6.Proprioception

The perception of movement and position in various parts of the body in the space is perceived as proprioception. Clinically, its measurements are usually based on the evaluation of the joint position sensation.Goniometer is used as a tool to measure the proprioceptive perception of the ankle joint. Subjects are placed in the starting position with their eyes closed. Ankle subtalar joint is in neutral position (STJN) and goniometer is set to zero [96].

20 degrees of inversion and 10 degrees of eversion are made passively to the ankle and taken into neutral position [97].The measurements are repeated 3 times and deviations from the target angle are measured with a goniometer [96].

Figure 3.5. Ankle Proprioception Measurement with Goniometer

3.3.Intervention

Before both training protocols, the participants did 3 sets of 12 repetitions of self ankle mobilization with theraband and 3 minutes of stretching exercises were performed after the training.

3.3.1.Neuromuscular Training Group

Single Leg Stance: Three repetitions were done with the eyes open.Subhjects were instructed to concentrate on a specific point on the wall throughout the repetition.When participants make 2 sets of 3 repetitions without error, they proceed to the next phase.

- Arms in cross position on the chest, 60 seconds on hard ground
- Arms in cross position on the chest, 30 seconds on Thera-Band Stability Trainer
- Arms in cross position on the chest, 60 seconds on Thera-Band Stability Trainer
- Arms in cross position on the chest, 30 seconds on BOSU ball
- Arms in cross position on the chest, 60 seconds on BOSU ball
- Arms in cross position on the chest, 30 seconds on Balance Disc
- Arms in cross position on the chest, 60 seconds on Balance Disc

• **Throwing the ball:** Physiotherapist throws ball for 30 seconds.Participant catched the ball and throwed it back to the physiotherapist.Participants tried to balance on single leg on a stable ground.

Single-Leg Hop: Participants made 5 jumps in each direction to the determined distance. These are the following directions: anterior/posterior, medial/lateral, anteromedial/posterolateral, and posteromedial/anterolateral.The participants jumped single leg from the starting point to the target point and returned to the starting point after maintaining their balance for 5 seconds.Participants made 5 repetitions in every direction without any mistakes before moving on to the next level.

1. Hopping 45.7-cm while hands free

2. Hopping 45.7-cm while hands on the hips

3. Hopping 68.6-cm while hands free

4. Hopping 68.6-cm while hands on the hips

5. Hopping 91.4-cm while hands free

6. Hopping 91.4-cm while hands on the hips

7.Hop and catch ball

Unanticipated Hop to Stabilization: 9 pieces of tape were placed on the floor of the test area at a distance of 45.7 cm between each other and an experiment was made by explaining to all participants. For each session, the number order is chosen at random.Participants jumped from the starting point to the target point single leg.After maintaining their balance, they jumped in the other direction selected.Participants completed the work by jumping to all areas.

1. Each move has a time limit of 5 seconds.
2. Each move has a time limit of 3 seconds
3. Each move has a time limit of 1 seconds
4. Foam pad added

Strength

- 4-way ankle theraband exercises
- Foot intrinsic strengthening (toe curl, doming)
- Heel raises exercise (3 sets × 12 reps)
- Squat, Lunge

3.3.2.Vestibular–Ocular Reflex Balance Group Rehabilitation Protocol

Single Leg Stance: Three repetitions were done with the eyes open.Subjectsw were instructed to concentrate on a specific point on the wall and turn their heads to the left and right with the speed of the metronome. The initial metronome speed was 60 beats per minute, and every week (every 3 sessions), the pace was increased by 20 beats per minute.

- Arms in cross position on the chest, 60 seconds on hard ground
- Arms in cross position on the chest, 30 seconds on Thera-Band Stability Trainer
- Arms in cross position on the chest, 60 seconds on Thera-Band Stability Trainer
- Arms in cross position on the chest, 30 seconds on BOSU ball
- Arms in cross position on the chest, 60 seconds on BOSU ball
- Arms in cross position on the chest, 30 seconds on Balance Disc
- Arms in cross position on the chest, 60 seconds on Balance Disc

• **Throwing the ball:** Physiotherapist throws ball for 30 seconds..Participant catched the ball and throwed it back to the physiotherapist.Participants tried to balance on single leg on a stable ground.

Single-Leg Hop: Participants made 5 jumps in each direction to the determined distance. These are the following directions: anterior/posterior, medial/lateral, anteromedial/posterolateral, and posteromedial/anterolateral. After jumping on the target and remaining in balance, they moved their heads to the left and right at the metronome speed for 10 second. The initial metronome speed was 60 beats per minute, and the pace was increased by 20 beats per minute every week (every three sessions). The participant returned to the starting point after 10 seconds of head movement.

1. Hopping 45.7-cm while hands free

2. Hopping 45.7-cm while hands on the hips

3. Hopping 68.6-cm while hands free

4. Hopping 68.6-cm while hands on the hips

5. Hopping 91.4-cm while hands free

6. Hopping 91.4-cm while hands on the hips

7.Hop and catch ball

Unanticipated Hop to Stabilization:9 pieces of tape were placed on the floor of the test area at a distance of 45.7 cm between each other and an experiment was made by explaining to all participants. For each session, the number order is chosen at random.Participants jumped from the starting point to the target point single leg. After jumping on the target and remaining in balance, they moved their heads to the left and right at the metronome speed for 10 seconds and jumped in the other direction selected. The initial metronome speed was 60 beats per minute, and the pace was increased by 20 beats per minute every week (every three sessions).

1. Each move has a time limit of 5 seconds.
2. Each move has a time limit of 3 seconds
3. Each move has a time limit of 1 seconds
4. Foam pad added

Table 3.1.Training Protocol for Neuromuscular Group

Neuromuscular Training	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Single-Leg Stance	Arms in cross position on the chest,60 seconds on hard ground Arms in cross position on the chest, 30 seconds on Thera-Band Stability Trainer	Arms in cross position on the chest, 60 seconds on Thera-Band Stability Trainer Arms in cross position on the chest, 30 seconds on BOSU ball	Arms in cross position on the chest, 60 seconds on BOSU ball Arms in cross position on the chest, 30 seconds on Balance Disc	Arms in cross position on the chest, 60 seconds on Balance Disc
Strength	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Double leg heel raises: (3 sets ×	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Double leg heel raises: (3 sets ×	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming)	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming)

	12reps)	12reps)	Squat (2sets × 10reps) Lunge (2 sets × 10reps)	Single leg heel raises: (3 sets × 12reps) Squat (2 sets × 10reps) Lunge (2 sets × 10reps)
Single-Leg Hop	Hopping 45.7-cm while hands free Hopping 45.7-cm while hands on the hips.	Hopping 68.6-cm while hands free Hopping 68.6-cm while hands on the hips	Hopping 91.4-cm while hands free Hopping 91.4-cm while hands on the hips	Hop and Ball Catch (5 repetition)
Single-Leg Ball Catch	Performed in 30 seconds on hard ground with a ball.	Performed in 30 seconds on Thera-Band Stability Trainer with a ball.	Performed in 30 seconds on on BOSUball with a ball.	Performed in 30 seconds on on Balance D isc with a ball.

Unanticipated Hop to Stabilization	Each move has a time limit of 5 seconds	Each move has a time limit of 3 seconds	Each move has a time limit of 1 seconds	Foam pad added

Table 3.2.Training Protocol for Vestibulo-ocular Reflex Training Group

Vestibulo-ocular Reflex Training	**Week 1**	**Week 2**	**Week 3**	**Week 4**
Single-Leg Stance	Arms in cross position on the chest,60 seconds on hard ground. Arms in cross position on the chest, 30 seconds on Thera-Band Stability Trainer Head movements with metronome speed was 60 beat	Arms in cross position on the chest, 60 seconds on Thera-Band Stability Trainer Arms in cross position on the chest, 30 seconds on BOSU ball Head movements with metronome	Arms in cross position on the chest, 60 seconds on BOSU ball Arms in cross position on the chest, 30 seconds on Balance Disc Head movements with metronome speed was 100 beat	Arms in cross position on the chest, 60 seconds on Balance Disc Head movements with metronome speed was 120beat

Strength	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Double leg heel raises: (3 sets × 12reps)	4 way ankle theraband exercises (3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Double leg heel raises: (3 sets × 12reps)	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Squat (2sets × 10reps) Lunge (2 sets × 10reps)	4 way ankle theraband exercises(3 sets × 12reps) Foot intrinsic strengthening (toe curl,doming) Single leg heel raises: (3 sets × 12reps) Squat (2 sets × 10reps) Lunge (2 sets × 10reps)
Single-Leg Hop	Hopping 45.7-cm while hands free Hopping 45.7-cm while hands on the hips.Head movements with	Hopping 68.6-cm while hands free Hopping 68.6-cm while hands on the hips.Head movements	Hopping 91.4-cm while hands free Hopping 91.4-cm while hands on the hips Head movements with	Hop and Ball Catch (5 repetition) Head movements with metronome speed was120 beat

	metronome speed was 60 beat	with metronome speed was 80 beat	metronome speed was 100 beat	
Single-Leg Ball Catch	Performed in 30 seconds on hard ground with a ball. Head movements with metronome speed was 60 beat	Performed in 30 seconds on on Thera-Band Stability Trainer with a ball. Head movements with metronome speed was 80 beat	Performed in 30 seconds on BOSUball with a ball.Head movements with metronome speed was 100 beat	Performed in 30 seconds on Balance Dics with a ball. Head movements with metronome speed was120 beat
Unanticipated Hop to Stabilization	Each move has a time limit of 5 seconds Head movements with metronome speed was 60 beat	Each move has a time limit of 3 seconds Head movements with metronome	Each move has a time limit of 1 seconds Head movements with metronome speed was 100 beat	Foam pad added Head movements with metronome speed was120 beat

		speed was 80 beat		

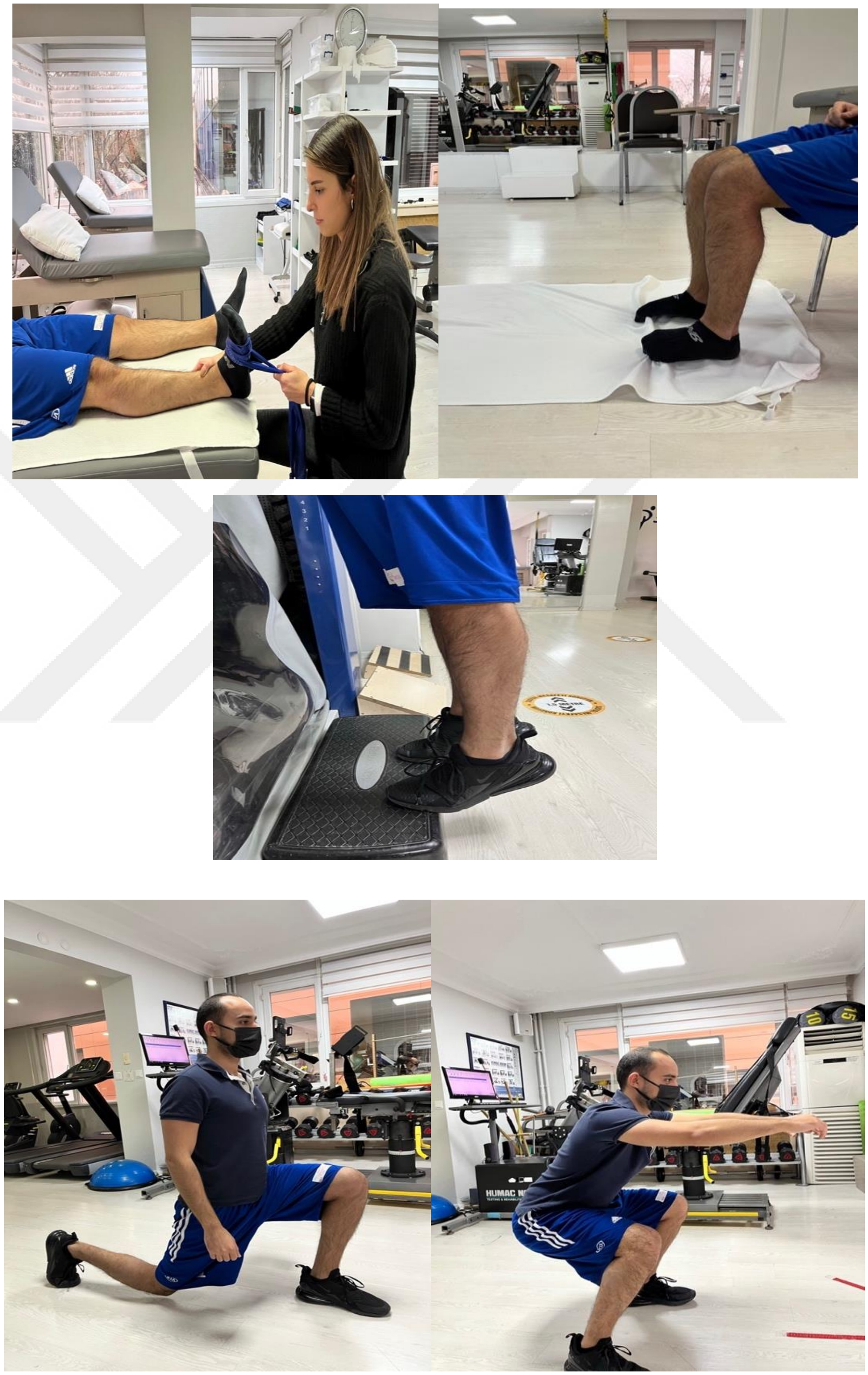


Figure 3.6. Strength Training

Figure 3.7. Single Leg Stance Exercise in the Neuromuscular Training Group

Figure 3.8. Single Leg Stance Exercise in the Vestibulo-ocular Reflex Training Grou

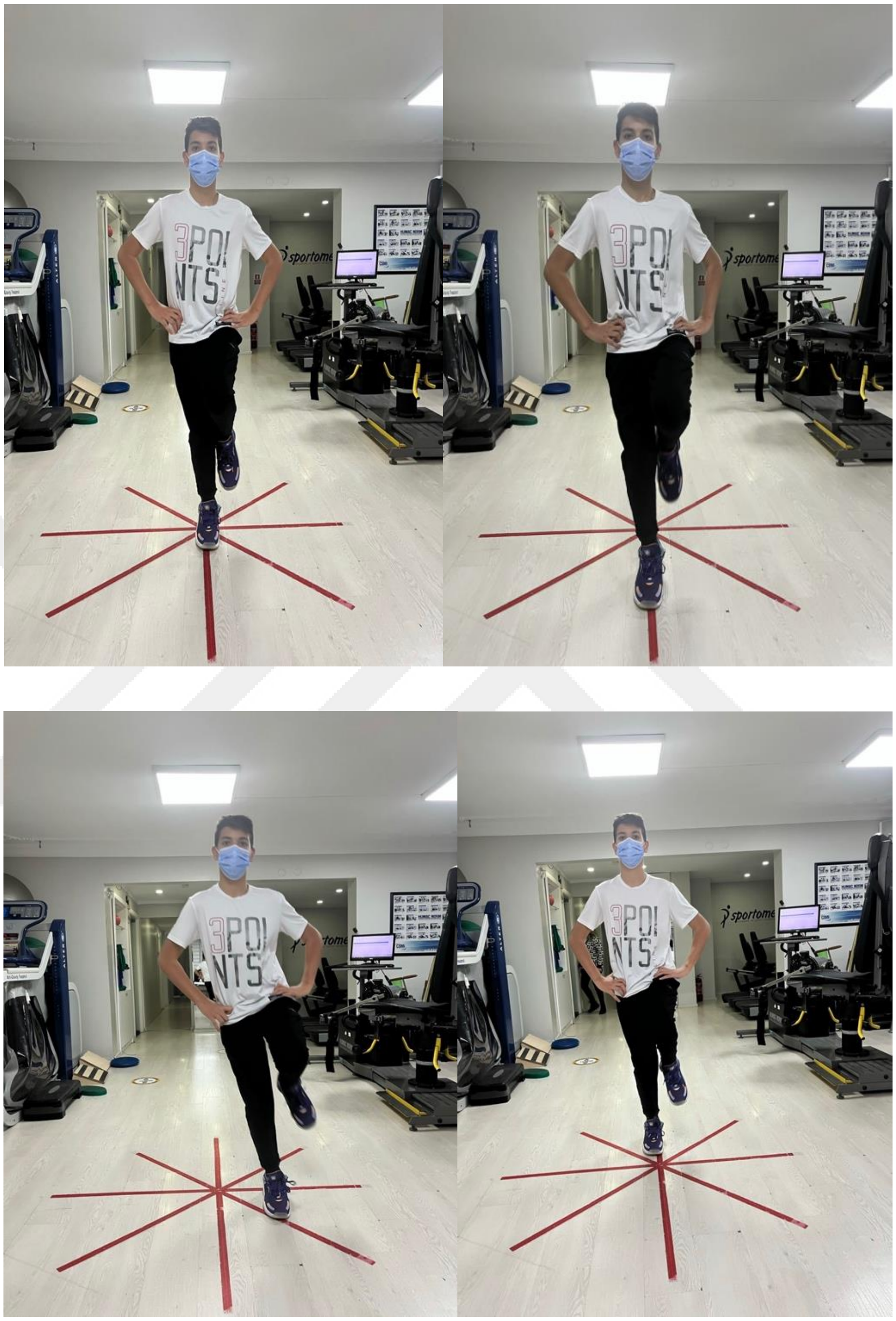


Figure 3.9. Single Leg Hop

3.4.Statiscal Analysis

The statistical analysis of the data obtained in our study was conducted using the Statistical Package for Social Science (SPSS) 22.0. Quantitative variables were presented using mean, standard deviation, median, minimum, and maximum values, while qualitative variables were presented using frequency and percentage values.. Averages of variables; arithmetic mean ± standard deviations (Mean±SD). Whether the variables conformed to the normal distribution was examined using the "Shapiro-Wilks" test statistic. The statistics of the findings before and after the treatment within the groups were made with the “Student’s paired sample t-test for dependent groups (Significance of Difference Between Two Spouses)”. The differences between the groups before and after the treatment were examined with the “t-test for independent groups (Significance Test of Difference Between Two Means)” and the differences were revealed. A $p<0.05$ value was accepted to determine the significance level of statistical differences. The p significance value in statistics was taken as $p<0.05$.

4.RESULTS

4.1.Physical Features of Participants

This study was conducted with volunteer participants who came to the Sportomed Clinic with a complaint of CAI (n=20) between the ages of 18-30 between September 2020 and April 2021.

The values of mean age, weight, height, and body mass index (BMI) of the NG, and VOG are presented in Table 4.1 According to these findings, there was no statistical difference in three groups in terms of age,weight,height,and BMI ($p>0.05$).

Table 4.1.Physical Features of Participants

	NG Mean ± SD	**VOG Mean ± SD**	**t**	**p value**
Age(year)	25.00± 4.89	23.90± 5.06	0.49	0.62
Weight(kg)	71.00± 12.61	65.20± 17.42	0.76	0.45
Height(m)	1.73± 8.01	1.78± 13.97	-0.94	0.35
BMI (kg/m2)	23.64± 4.62	20.52± 2.73	1.83	0.08

Data expressed as mean ± standard deviation. BMI: Body mass index. NG: Nöromuscular Group, VOG: Vestibulo-ocular Group

4.2.Distribution of Gender, Dominant Hand and Unstable Ankle Values in the Study Groups and Between Groups

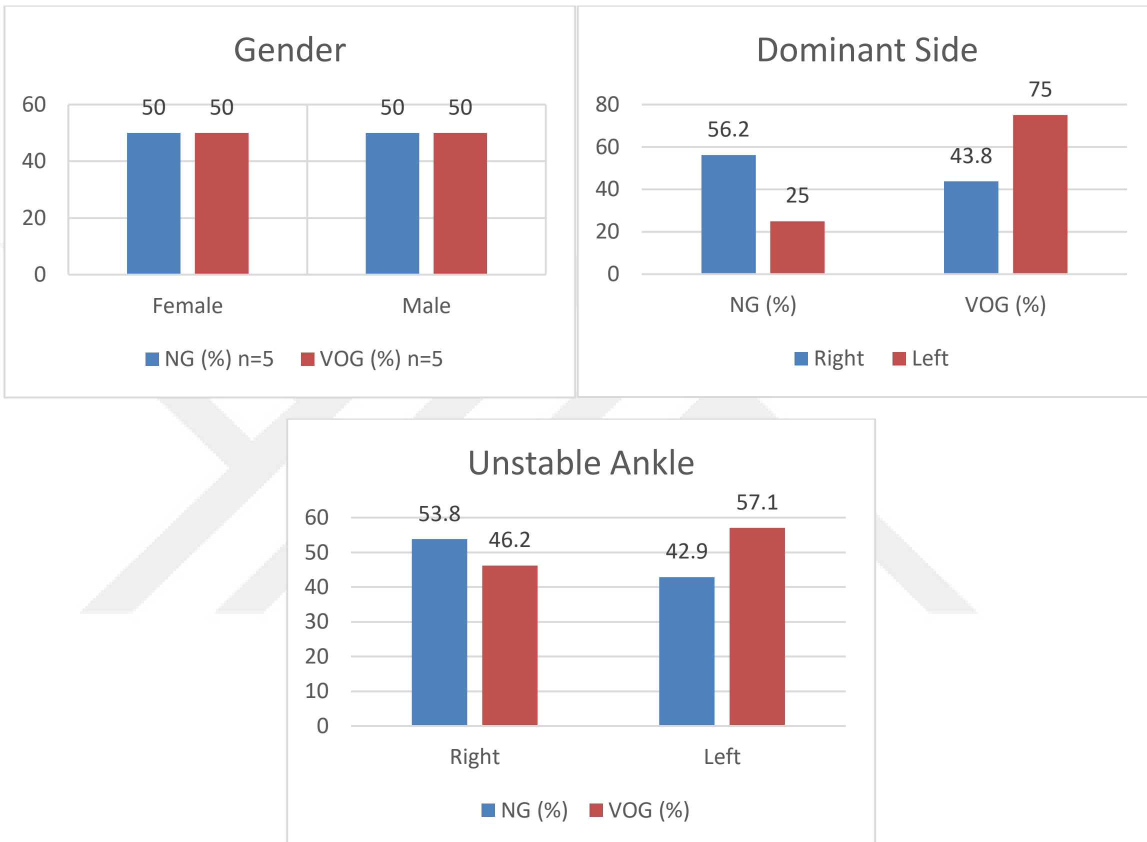
The gender, dominant side and unstable side in the study groups were given Table As a result of the statistical analysis of these values, no statistical difference was found between the two groups **(p>0.05), (Table 4.2).**

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

		NG (%) (n)	VOG (%) (n)	λ^2	P
Gender	**Female**	50.0 (5)	50.0 (5)	0.00	0.58
	Male	50.0 (5)	50.0 (5)		
Dominant side	**Right**	56.2 (9)	43.8 (7)	1.25	1.00
	Left	25.0 (1)	75.0 (3)		
Unstable Ankle	**Right**	53.8 (7)	46.2 (3)	0.22	1.00
	Left	42.9 (6)	57.1 (4)		

Data expressed as % (n). NG: Nöromuscular Group, VOG: Vestibulo-Ocular Group.

Graph 4.1. Distribution of Gender, Dominant Side and Unstable Ankle Values in the Study Groups



4.3.Intergroup Comparison of Pre-treatment FAAM Score and Number of Ankle Sprain

The FAAM-ADL and FAAM Sport score of unstable ankle side and the number of ankle sprain history of two groups were given Table 4.3. When the values of FAAM-ADL, FAAM sport scores, and the number of ankle sprains were examined, no statistical difference was found between the two groups **(p>0.05), (Table 4.3).**

Table 4.3. Comparison of FAAM Score and Number of Ankle Sprain History among the Study Groups

	NG Mean ± SD	VOG Mean ± SD	t	p value
FAAM-ADL	83.10±5.02	80.90±6.40	0.85	0.40
FAAM SPORT	64.30±6.70	62.00±6.92	0.75	0.46
Number of Ankle Sprain	4.70±1.49	5.80±2.69	-1.127	0.27

Data expressed as mean ± standard deviation. FAAM: Foot and Ankle Ability Measure NG: Nöromuscular Group, VOG: Vestibulo-Ocular Group

4.4.Intergroup Comparison of Pre-Treatment Findings

Independent sample t test was used for parametric variables to compare the variables between groups for pre-treatment evaluations methods.

4.4.1.Intergroup Comparison of Pre-treatment Findings for Ankle Range of Motion and Proprioception

According to the statistical analysis, there was no significant difference in ankle range of motion in dorsiflexion, plantarflexion, inversion, and eversion between the groups, and no statistical difference in ankle proprioception in inversion and eversion between the groups for both ankles **(p>0.05), (Table 4.4).**

Table 4.4. Intergroup Comparison of Pre-treatment Findings for Ankle Range of Motion and Proprioception

Ankle ROM		**NG Mean ± SD**	**VOG Mean ± SD**	**t**	**p value**
Dorsiflexion	**Stable**	12.90±2.28	13.50±2.22	-0.59	0,55
	Unstable	11.10±0.99	11.60±2.11	-0.67	0.50
Plantarflexion	**Stable**	43.30±4.80	45.90±7.97	-0.88	0.38
	Unstable	40.00±4.47	44.00±8.09	-1.36	0.18
Inversion	**Stable**	25.80±5.07	30.00±3.80	-2.09	0.05
	Unstable	28.90±5.98	29.60±6.31	-0.25	0.80
Eversion	**Stable**	20.80±3.22	24.80±5.13	-2.08	0.05
	Unstable	18.90±3.24	24.00±9.43	-1.61	0.12
Ankle Proprioception					
Inversion	**Stable**	3.60 ±2.67	3.50 ±1.71	0.10	0.92
	Unstable	5.10 ±3.34	5.30 ±1.63	-0.17	0.86
Eversion	**Stable**	1.80±1.31	3.00 ±1.88	-1.65	0.11
	Unstable	3.60±1.57	6.80 ±5.07	-1.95	0.73

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent test.

4.4.2.Intergroup Comparison of Pre-Treatment Findings for Star Excursion Balance Test

Comparing the groups for pre-treatment findings of Star Execursion Balance values were showed that no statistical differences were found in the anterior, posterior, medial, lateral,anteromedial (AM),anterolateral (AL),postreomedial (PM) and posterolateral (PL) direction **(p>0.05) (Table 4.5).**

Table 4.5.Intergroup Comparison of Pre-Treatment Findings for Star Excursion Balance Test

Star Excursion Balance		NG Mean ± SD	VOG Mean ± SD	t	p value
Anterior	**Stable**	79.70±10.76	79.00±8.73	0.16	0.87
	Unstable	74.30±9.61	74.30±10.01	0.00	1.00
Posterior	**Stable**	76.20±15.94	86.40±11.65	-1.63	0.12
	Unstable	68.30±15.86	80.60±9.59	-2.09	0.05
Anteromedial	**Stable**	76.00±8.62	81.00±9.16	-1.25	0.22
	Unstable	74.20±11.57	77.40±10.36	-0.65	0.52
Anterolateral	**Stable**	63.40±8.38	64.30±12.92	-0.18	0.85
	Unstable	58.60±9.27	57.80±12.43	0.16	0.87
Medial	**Stable**	77.90±11.62	78.90±11.62	-0.19	0.85
	Unstable	74.40±13.55	75.20±11.30	-0.14	0.88
Lateral	**Stable**	55.80±9.16	59.30±14.48	-0.64	0.52
	Unstable	51.10±11.48	52.00±14.12	-0.15	0.87
Posteromedial	**Stable**	78.40±12.24	81.60±14.85	-0.52	0.60
	Unstable	73.40±14.14	78.20±13.65	-0.77	0.45
Posterolateral	**Stable**	64.30±10.99	74.00±13.74	-1.74	0.98
	Unstable	61.00±10.42	69.90±13.29	-1.66	0.11

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t tes

4.4.3.Intergroup Comparison of Pre-Treatment Finding for Isokinetic Muscle Strength

According to variables of pre-treatment, no statistical difference was found between the groups for both ankles in terms of inversion and eversion isokinetic muscle strenght **($p>0.05$), (Table 4.6).**

Table 4.6.Intergroup Comparison of Pre-Treatment Finding for Isokinetic Muscle Strength

Isokinetic Muscle Strength		NG Mean ± SD	VOG Mean ± SD	T	p value
Inversion 60^0/s	**Stable**	32.80±11.39	32.20±8.33	0.13	0.89
	Unstable	28.50±11.24	30.90±12.81	-0.44	0.66
Eversion 60^0/s	**Stable**	25.50±6.83	28.50±8.91	-0.84	0.40
	Unstable	19.80±7.77	26.30±9.70	-1.65	0.11
Inversion 120^0/s	**Stable**	26.90±9.02	24.30±6.99	0.72	0.48
	Unstable	23.70±8.17	23.40±8.57	0.08	0.93
Eversion 120^0/s	**Stable**	20.50±6.13	21.80±7.05	-0.44	0.66
	Unstable	16.50±5.33	18.60±5.44	-0.87	0.39
Inversion 180^0/s	**Stable**	22.20±6.03	23.60±5.25	-0.55	0.58
	Unstable	19.40±6.36	21.60±6.75	-0.75	0.46
Eversion 180^0/s	**Stable**	17.90±6.06	18.60±2.75	-0.33	0.74
	Unstable	15.40±4.71	16.20±3.79	-0.41	0.68

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t test.

4.5.Intragroup Comparison of Pre- and Post-Treatment Findings

A paired t-test for parametric variables was used to examine the differences between group variables in terms of pre- and post-treatment findings.

4.5.1.Intragroup Comparison of Pre- and Post-Treatment Findings for Ankle Range of Motion

As a result of statistical analysis, a significant difference was found in dorsiflexion and plantarflexion on the unstable side of both groups in the pre- and post-treatment evaluations **($p<0.05$).** While the eversion angle on the unstable side was significant in the neuromuscular group, no significant difference was found in the vestibulo-ocular group before and after treatment. There was no significant difference in inversion angle before and after treatment in both groups **($p>0.05$), (Table 4.7).**

Table 4.7. Intragroup Comparison of Pre- and Post-Treatment Findings for Ankle Range of Motion

Ankle ROM			**NG Mean ± SD**	**t/p**	**VOG Mean ± SD**	**t/p**
Dorsiflexion	**Stable**	**Pre**	12.90±2.28	-1.62 0.13	13.50 ±2.22	-1.50 0.16
		Post	12.40±1.89		13.90 ±1.72	
	Unstable	**Pre**	11.10±0.99	-6.33 **0.00***	11.60 ±2.11	-9.79 **0.00***
		Post	12.50±0.97		13.20 ±1.87	
Plantarflexion	**Stable**	**Pre**	43.30±4.80	-1.87 0.09	45.90 ±7.97	-1.50 0.16
		Post	44.40±3.86		46.50 ±7.61	
	Unstable	**Pre**	40.00±4.47	-5.07 **0.00***	44.00 ±8.09	-4.63 **0.00***
		Post	43.40±4.00		45.80 ±7.03	
Inversion	**Stable**	**Pre**	25.80±5.07	-0.85 0.41	30.00 ±380	0.00 1.00
		Post	26.30±3.62		30.00 ±3.82	
	Unstable	**Pre**	28.90±5.98	0.55 0.59	29.60 ±6.31	0.93 0.92
		Post	28.30±3.62		29.50 ±5.40	
Eversion	**Stable**	**Pre**	20.80±3.22	-2.23 0.05	24.80 ±5.13	-1.86 0.09
		Post	21.30±3.16		25.70 ±5.69	
	Unstable	**Pre**	18.90±3.24	-5.65 **0.00***	24.00 ±9.43	-1.52 0.16
		Post	21.10±2.37		25.90 ±7.92	

Data expressed as mean ± standard deviation. ROM:Range of Motion, NG:Nöromuscular Group, VOG:Vestibulo-ocular Group.Paired sample t test.

4.5.2.Intragroup Comparison of Pre-and Post-Treatment Findings for Ankle Proprioception

When we compared the pre- and post-treatment findings, a statistically significant difference was found in the unstable side in both groups **($p<0.05$),(Table 4.8).**

Table 4.8. Intragroup Comparison of Pre-and Post-Treatment Findings for Ankle Proprioception

Ankle Proprioception			**NG Mean ± SD**	**t/p**	**VOG Mean ± SD**	**t/p**
Inversion	**Stable**	**Pre**	3.60±2.67	2.40 0.39	3.50±1.71	1.58 0.14
		Post	2.20±1.68		2.60±1.07	
	Unstable	**Pre**	5.10±3.34	4.79 **0.00**	5.30±1.63	8.18 **0.00**
		Post	2.60±1.95		2.20±0.91	
Eversion	**Stable**	**Pre**	1.80±1.31	0.00 1.00	3.00±1.88	0.72 0.48
		Post	1.80±1.03		2.50±2.12	
	Unstable	**Pre**	3.60±1.57	5.58 **0.00**	6.80±5.07	4.01 **0.00**
		Post	2.10±1.19		1.70±1.94	

Data expressed as mean ± standard deviation.NG: Nöromuscular Group, VOG:Vestibulo-ocular Group.Paired sample t test.

4.5.3.Intragroup Comparison of Pre and Post-Treatment Findings for Isokinetic Muscle Strength

A significant difference was found in invertor and evertor isokinetic muscle strength at 60 º/sn ,120 º/sn and 180 º/sn angular velocities in both groups on the unstable side **($p<0.05$).** While there was a significant difference in evertor and invertor muscle strength on the stable side at all angular velocities,no significant difference found in invertor,evertor muscle strength at 60 º/sn and invertor muscle strenght at 120 º/sn angular velocities on the vestibulo-ocular group (**Table 4.9).**

Table 4.9.Intragroup Comparison of Pre and Post-Treatment Findings for Isokinetic Muscle Strength

Isokinetic Muscle Strength			NG Mean ± SD	t/p	VOG Mean ± SD	t/p
Inversion 60 °/sn	**Stable**	**Pre**	33.50±10.51	-4.11	32.80±8.33	-1.90
		Post	36.60±10.67	**0.03**	36.10±9.85	0.08
	Unstable	**Pre**	28.50±11.24	-6.24	30.90±12.81	-4.91
		Post	34.90±10.96	**0.00**	36.70±13.53	**0.00**
Eversion 60 °/sn	**Stable**	**Pre**	25.50±6.83	-5.77	28.50±8.91	-2.02
		Post	29.70±7.66	**0.00**	33.70±6.99	0.07
	Unstable	**Pre**	19.80±7.71	-11.78	26.30±9.07	-4.79
		Post	29.30±9.67	**0.00**	34.80±8.03	**0.00**
Inversion 120 °/sn	**Stable**	**Pre**	27.30±8.99	-4.44	24.30±6.99	-2.20
		Post	29.60±8.87	**0.00**	28.50±6.96	0.05
	Unstable	**Pre**	23.70±8.17	-5.46	23.40±8.57	-3.40
		Post	29.40±9.14	**0.00**	30.70±9.86	**0.00**
Eversion 120 °/sn	**Stable**	**Pre**	20.50±6.13	-3.35	21.80±7.05	-2.72
		Post	23.60±7.83	**0.00**	26.90±5.95	**0.02**
	Unstable	**Pre**	16.50±5.33	-4.75	18.60±5.44	-5.30
		Post	24.10±8.37	**0.01**	27.70±6.84	**0.00**
Inversion 180 °/sn	**Stable**	**Pre**	22.20±6.03	-3.54	23.60±5.25	-2.25
		Post	25.90±6.93	**0.00**	27.90±7.07	**0.02**
	Unstable	**Pre**	19.40±6.36	-5.32	21.60±6.75	-5.09
		Post	25.00±7.80	**0.00**	28.50±8.64	**0.00**
Eversion 180 °/sn	**Stable**	**Pre**	17.90±6.06	-3.19	18.90±2.84	-4.52
		Post	21.20±6.71	**0.01**	21.80±4.04	**0.00**
	Unstable	**Pre**	15.40±4.71	-4.74	16.20±3.79	-4.09
		Post	21.60±7.58	**0.01**	20.70±4.21	**0.00**

Data expressed as mean ± standard deviation.NG: Nöromuscular Group, VOG:Vestibulo-ocular Group.Paired sample t test.

4.5.4.Intragroup Comparison of Pre- and Post Treatment Findings for Star Excursion Balance Test

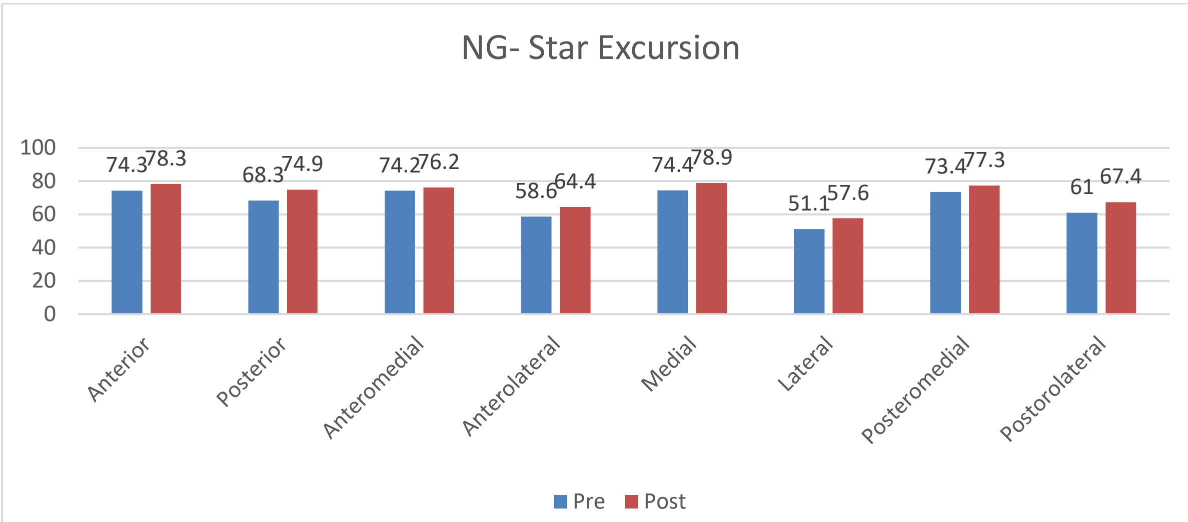
According to the paired sample t test results, significant differences were found for within-group variables between study groups to reach distance anterior, posterior, medial, lateral, posteromedial, posterolateral directions in the star excursion balance test **($p<0.05$).** While there was a significant difference in the AM direction in the vestibulo-ocular group, no significant difference was found in the neuromuscular group. There was a significant difference was found for within-group variables between study groups to reach distance medial direction on a stable foot. When the pre and post-measurement findings of reach distance in AL direction of the stable ankle were compared significant differences was observed in the neuromuscular group, while a significant difference was observed in the vestibulo-ocular group in the PM direction **(Table 4.10).**

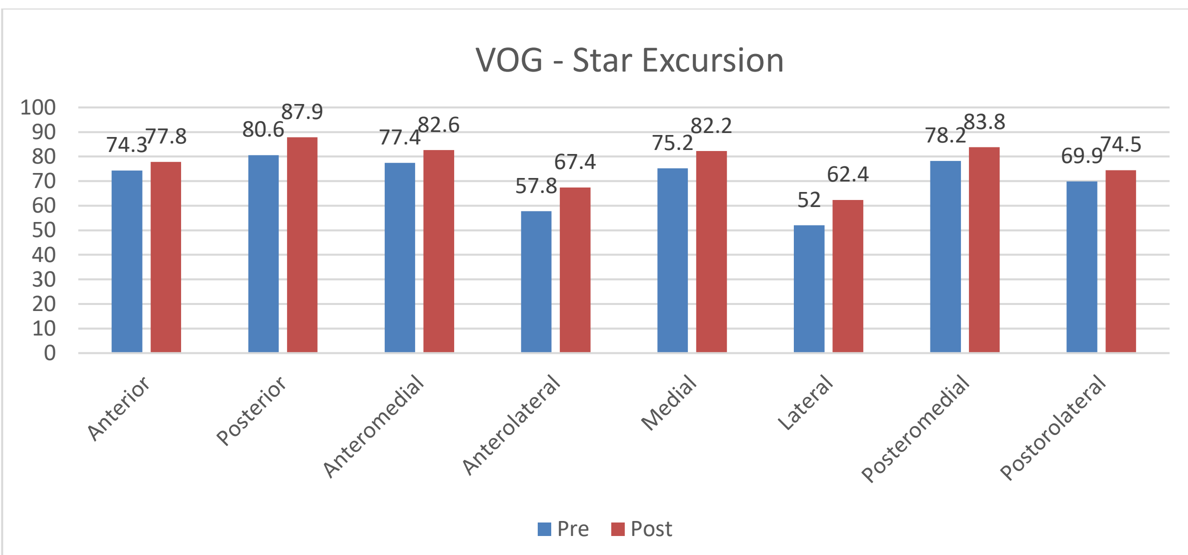
Table 4.10. Intragroup Comparison of Pre- and Post Treatment Findings for Star Excursion Balance

Star Excursion Balance			NG Mean ± SD	t/p	VOG Mean ± SD	t/p
Anterior	**Stable**	**Pre**	79.70±10.76	-0.90	79.00±8.73	-0.60
		Post	80.40±9.86	0.39	79.50±9.84	0.56
	Unstable	**Pre**	74.30±9.61	-4.74	74.30±10.01	-5.82
		Post	78.30±10.43	**0.00**	77.80±9.82	**0.00**
Posterior	**Stable**	**Pre**	76.20±15.94	-1.62	86.40±11.65	-0.42
		Post	78.70±16.02	0.13	87.00±13.29	0.67
	Unstable	**Pre**	68.30±15.86	-4.40	80.60±9.59	-6.72
		Post	74.90±17.50	**0.00**	87.90±12.05	**0.00**
Anteromedial	**Stable**	**Pre**	76.00±8.62	-1.41	81.00±9.16	-1.20
		Post	77.80±9.22	0.19	82.80±8.57	0.26
	Unstable	**Pre**	74.20±11.57	-1.60	77.40±10.36	-3.50
		Post	76.20±10.14	0.14	82.60±9.38	**0.00**
Anterolateral	**Stable**	**Pre**	63.40±8.38	-2.45	64.30±12.92	-0.65
		Post	66.70±10.81	**0.03**	66.70±6.20	0.52
	Unstable	**Pre**	58.60±9.27	-3.24	57.80±12.43	-2.72
		Post	64.40±11.37	**0.01**	67.40±6.80	**0.00**
Medial	**Stable**	**Pre**	77.90±11.62	-3.25	78.90±11.62	-2.55
		Post	79.70±12.04	**0.01**	82.40±12.28	**0.03**
	Unstable	**Pre**	74.40±13.55	-6.13	75.20±11.30	-5.09
		Post	78.90±12.16	**0.00**	82.20±10.37	**0.00**
Lateral	**Stable**	**Pre**	55.80±9.16	-2.24	59.30±14.48	-2.38
		Post	58.70±10.15	0.05	64.70±13.50	0.04
	Unstable	**Pre**	51.10±11.48	-7.92	52.00±14.12	-4.73
		Post	57.60±13.17	**0.00**	62.40±13.11	**0.00**
Posteromedial	**Stable**	**Pre**	78.40±12.24	-0.10	81.60±14.85	-3.76
		Post	78.50±10.73	0.92	85.70±15.26	**0.00**
	Unstable	**Pre**	73.40±14.14	-3.20	78.20±13.65	-5.19
		Post	77.30±12.75	**0.01**	83.80±12.73	**0.00**
Posterolateral	**Stable**	**Pre**	64.30±10.99	-4.46	74.00±13.74	-2.44
		Post	68.50±13.13	0.00	76.00±12.73	0.03
	Unstable	**Pre**	61.00±10.42	-6.77	69.90±13.29	-5.43
		Post	67.40±12.29	**0.00**	74.50±13.30	**0.00**

Data expressed as mean ± standard deviation.NG:Nöromuscular Group, VOG:Vestibulo-ocular Group.Paired sample t test

Graphs 4.2. The Improvemens of Star Excursion Balance Test After Neuromuscular and Vestibulo-ocular Training





4.5.5.Intragroup Comparison of Pre- and Post-Treatment Findings for FAAM and FAAM Sport Score

When the FAAM-ADL and FAAM Sport values pre and post treatment findings were compared, statistically significant difference was observed in both groups **($p<0.05$), (Table 4.11).**

Table 4.11.Intragroup Comparison of Pre- and Post-Treatment Findings for FAAM and FAAM Sport Score

FAAM			NG Mean ± SD	t/p	VOG Mean ± SD	t/p
FAAM-ADL	**Unstable**	**Pre**	83.10±5.02	-14.10 **0.00**	80.90±6.40	-12.10 **0.00**
		Post	90.40±4.50		90.00±4.92	
FAAM SPORT	**Unstable**	**Pre**	64.30±6.70	-10.17 **0.00**	62.00±6.92	-29.99 **0.00**
		Post	78.70±6.00		79.20±6.12	

Data expressed as mean ± standard deviation. FAAM: Foot and Ankle Ability Measure ADL: Activity of Daily Living S: Sports, NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Paired sample t test.

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

Independent samples t-test was performed for parametric variables to compare the difference between the pre- and post-treatment findings between the groups.

4.6.1.Intergroup Comparison of Differences Between Post-Treatment Finding for Ankle Range of Motion

As a result of the analysis, no significant difference was found in the range of motion before and after treatment, except for the inversion of the stable foot **(p>0.05), (Table 4.12).**

Table 4.12.Intergroup comparison of differences between post-treatment finding for Ankle Range of Motion

Ankle ROM		**NG Mean ± SD**	**VOG Mean ± SD**	**T**	**p value**
Dorsiflexion	**Stable**	12.40±1.89	13.90±1.72	-0.61	0.54
	Unstable	12.50±0.97	13.20±1.87	-1.80	0.08
Plantarflexion	**Stable**	43.30±4.80	45.90±7.97	-0.77	0.44
	Unstable	43.50±4.00	45.80±7.03	-1.29	0.21
Inversion	**Stable**	26.30±3.62	30.00±3.82	-2.22	**0.04**
	Unstable	28.30±3.62	29.50±5.40	-0.58	0.56
Eversion	**Stable**	21.30±3.16	25.70±5.69	-2.13	0.47
	Unstable	21.10±2.37	25.90±7.92	-1.83	0.83

Data expressed as mean ± standard deviation. ROM:Range of Motion, NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t test.

4.6.2.Intergroup Comparison of Differences Between Post-Treatment Finding for Ankle Proprioception

When the statistical data was analyzed for intergroup comparison, as presented in Table 4.13, there was no statistical differences between post-treatment results in ankle proprioception **(p>0.05)**

Table 4.13. Intergroup comparison of differences between post-treatment finding for Ankle Proprioception

Ankle Proprioception		NG Mean ± SD	VOG Mean ± SD	t	p value
Inversion	**Stable**	2.20 ±1.68	2.60 ±1.07	-0.93	0.36
	Unstable	2.60±1.95	2.20±0.91	0.55	0.58
Eversion	**Stable**	1.80±1.03	2.50±2.12	-0.63	0.53
	Unstable	2.10±1.19	1.70±1.94	0.58	0.56

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t test

4.6.3.Intergroup Comparison of Differences Between Post-Treatment Finding for Star Excursion Balance

According to Independent t test, there were not significant differences for intergroup variables between study groups to reach distance in the anterior, posterior,medial,lateral,AM,AL,PM and PL directions **(p>0.05), (Table 4.14).**

Table 4.14.Intergroup comparison of differences between post-treatment finding for Star Excursion Balance

Star Excursion Balance		NG Mean ± SD	VOG Mean ± SD	t	p value
Anterior	**Stable**	80.40±9.86	79.50±9.84	0.20	0.84
	Unstable	78.30±10.43	77.80±9.82	0.11	0.91
Posterior	**Stable**	78.70±16.02	87.00±13.29	-1.26	0.22
	Unstable	74.90±17.50	87.90±12.05	-1.93	0.06
Anteromedial	**Stable**	77.80±9.22	82.80±8.57	-1.25	0.22
	Unstable	76.20±10.14	82.60±9.38	-1.46	0.16
Anterolateral	**Stable**	66.70±10.81	66.70±6.20	0.00	1.00
	Unstable	64.40±11.37	67.40±6.80	-0.71	0.48
Medial	**Stable**	79.70±12.04	82.40±12.28	-0.49	0.62
	Unstable	78.90±12.16	82.20±10.37	-0.65	0.52
Lateral	**Stable**	58.70±10.15	64.70±13.05	-1.12	0.27
	Unstable	57.60±13.17	62.40±13.11	-0.81	0.42
Posteromedial	**Stable**	78.50±10.73	85.70±15.26	-1.22	0.23
	Unstable	77.30±12.75	83.80±12.73	-1.14	0.26
Posterolateral	**Stable**	68.50±13.13	76.00±12.73	-1.29	0.21
	Unstable	67.40±12.29	74.50±13.30	-1.24	0.23

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t test.

4.6.4.Intergroup Comparison Of Differences Between Post-Treatment Finding for Isokinetic Muscle Strength

When the isokinetic muscle strength values before and after the treatment were compared, no significant difference was found between the two study groups **($p>0.05$), (Table 4.15).**

Table 4.15.Intergroup comparison of differences between post-treatment finding for Isokinetic Muscle Strength

Isokinetic Muscle Strength		NG Mean ± SD	VOG Mean ± SD	t	p value
Inversion 60^0/s	**Stable**	38.20±12.40	36.00±9.85	0.43	0.66
	Unstable	35.30±11.28	36.70±13.53	-0.25	0.80
Eversion 60^0/s	**Stable**	33.20±9.11	33.70±6.99	-0.13	0.89
	Unstable	29.30±9.67	34.80±8.03	-1.38	0.18
Inversion 120^0/s	**Stable**	30.50±8.04	30.00±7.07	0.14	0.88
	Unstable	29.40±9.14	30.70±9.86	-0.30	0.76
Eversion 120^0/s	**Stable**	24.80±8.32	28.50±5.87	-1.14	0.26
	Unstable	24.10±8.37	27.70±6.84	-1.05	0.30
Inversion 180^0/s	**Stable**	27.30±8.15	29.40±8.09	-0.57	0.57
	Unstable	25.00±7.80	28.50±8.64	-0.95	0.35
Eversion 180^0/s	**Stable**	21.20±6.71	22.80±4.73	-0.61	0.54
	Unstable	21.60±7.58	21.70±5.12	-0.03	0.97

Data expressed as mean ± standard deviation. NG:Nöromuscular Group, VOG:Vestibulo-ocular Group.

Independent t test

4.6.5.Intergroup Comparison of Differences Between Post-Treatment Finding for FAAM-ADL and FAAM Sport Score

Independent t test was used to compare the difference between pre and post measurements findings of FAAM-ADL and FAAM-S between groups. There was no statistical difference between NG and VOG **(p>0.05), (Table 4.16).**

Table 4.16. Intergroup comparison of differences between post-treatment finding for FAAM-ADL and FAAM Sport Score

FAAM	NG Mean ± SD	VOG Mean ± SD	t	p value
FAAM-ADL	90.40±4.50	90.00±4.92	0.19	0.85
FAAM SPORT	78.70±6.00	79.20±6.12	-0.18	0.85

Data expressed as mean ± standard deviation. FAAM: Foot and Ankle Ability Measure ADL: Activity of Daily Living S: Sports, NG:Nöromuscular Group, VOG:Vestibulo-ocular Group. Independent t test.

5.DISCUSSION

Since the ankle is the highly traumatized body part in sports injuries accounting for 10-30% of all sports injuries, many studies have shown that 2-7 individuals per 1000 are affected each year in the general population [98]. Chronic ankle instability is characterized by recurrent sprains, mechanical instability, a sensation of the ankle giving way, functional instability, pain, and edema.Recent research has shown that comprehensive rehabilitation strategies (strength,balance,postural control,flexibilty and agility) result in significant positive improvements, often better than the recovery observed with traditional rehabilitation strategies, and exercise has been identified as the most important component [99,100]. However, most of these studies in the literature include the effectiveness of neuromuscular training, and studies examining the effects of vestibulo-ocular reflex training on chronic ankle instability are insufficient.Therefore,we compared the effects of neuromuscular exercise training and combined vestibulo-ocular reflex training with neuromuscular exercise on balance (SEBT), isokinetic muscle strength and proprioception (JPS) in people with chronic ankle instability. According to the main findings of our study, we found improvements in self-reported function (FAAM-ADL and FAAM-Sports), dynamic postural control (SEBT), proprioception (JPS), and isokinetic strength parameters after a 4-week exercise program in both groups ($p<0.05$). However, when we compared the groups, we did not find significant differences in these parameters before and after treatment ($p>0.05$).

In the literature, there are systematic reviews that include the effectiveness of functional rehabilitation protocols for treating dysfunction associated with chronic ankle instability. These studies have shown that neuromuscular training, which consists of a combination of functional-based exercises such as postural stability, proprioceptive, and strength training, improves self-reported function, static and dynamic balance in people with chronic ankle instability [101].In the study of Mckenon et al., the subjects were randomly divided into 2 groups and the individuals in the balance group (n=16; 22.2±4.5 yr)were given 4-week progressive balance training, the control group (n=15; 19.5 ±1.2 yr) did not participate in any exercise training.In the progressive balance training program, individuals tried to maintain their balance while performing hop to stabilization, hop to stabilization and reaching, hop to stabilization box drill, eyes open and closed during one leg stance. They found improvements in static postural control and self-reported function in the balance group at the end of the study [102]. In the study by Anguish, et al., college students with chronic ankle instability were treated for 4 weeks. The subjects were randomly divided into progressive jump stabilization training group (n=9) and single leg balance training group (n=9). During the 4-week treatment period, FAAM-ADL and FAAM-S values improved from pre-intervention to post-intervention in the PHSB and SLB groups, but neither group out performed the other statistically [103]. In another study, Minoonejad et al. published 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 [104] . This finding, supported by improvements in our SEBT and FAAM scores, showed that both groups improved after participating in 4-week CAI rehabilitation protocols in our study.Similar to these studies, we used balance exercise strategies within neuromuscular training and used the FAAM-ADL and FAAM-S scales to evaluate the self-reported functional levels of the individuals.At the end of the study, we found significant differences in the values before and after the treatment, but we did not find any superiority between the two groups ($p < 0.05$, Table 4.11, Table 4.16). Therefore, we can say that both of our CAI protocols were therapeutically effective, as both treatment groups' FAAM-ADL and FAAM-Sports subscale scores improved the clinically and statistically significant difference.Postural control has been shown to be a predictor of the development of ankle joint injury in the literature, and deficits in postural stability have been shown to be a sign of the development of CAI [45,82].Also,various balance training programs have been observed to improve postural control in CAI patients, but it is unknown which type is superior in terms of improving postural control and function [82].Sefton et al., included people with chronic ankle instability (n=12 ; 21.2 ±2.1 years)and healthy individual (n=9 ; 20.8±1.3 years) in their study, and individuals with chronic ankle instability were included in 6-week balance training. Healthy individuals were the control group and did not receive any training. In the study, dynamic postural stability was investigated with the modified star excursion balance test (SEBT).They found that at the end of 6 weeks, people with chronic ankle instability had better reach distances in the AM, medial, and PM directions than the control group [105].In another study, Anguish et al. they gave traditional balance training (n=9) to one group and progressive balance training to the other group (n=9). When they compared the results, they showed that there was an improvement in the star excursion balance test performed before and after the treatment in both groups, but there was no significant difference between the two groups.In addition, they showed in their study that the postero-lateral and postero-medial access distances were better and the anterior access distances were more moderate. They suggested that this is due to the altered biomechanics of the ankle joint and the presence of limitation of range of motion (ROM) in patients with CAI [102]. In another similar study,Hilgendorf et al. divided individuals into two groups in their study; traditional balance exercise group (n=8) and vestibulo-ocular reflex training group (n=8). Rehabilitation programs include single-leg stance,hop to stabilization exercises for the balance group, and side to side head movements together with balance exercises for the vestibulo-ocular reflex training group. They examined dynamic visual acuity (DVA), gaze stability (GS) and modified overall stability index scores at the end of the 4-week training and found better DVA, GS and balance scores in the vestibulo-ocular reflex training group. Unlike our study, they found superiority in dynamic stability in the vestibulo-ocular group when compared to the traditional balance group. We thought that this difference might be due to the fact that neuromuscular training in our study was more comprehensive than balance training [6]. Similar to previous studies,in our study, we used SEBT to evaluate dynamic balance and postural stability, and after 4 weeks of neuromuscular and vestibulo-ocular exercise training, improvements were observed in both groups in pre-treatment and post-treatment on all SEBT reach directions ($p<0.05$, Table 4.14.). When we compared the pre- and post-treatment SEBT measurements within the groups, we found a significant improvement AM direction in the vestibulo-ocular group, but not in the neuromuscular group.No superiority was found between the two groups in other directions ($p>0.05$, Table 4.10). When we compared our findings, we thought that these changes in both groups after treatment could lead to a significant improvement in dynamic postural control due to the reduction of restrictions applied to the sensorimotor system, and that the difference in AM directions between the two groups could be due to biomechanical differences in the ankle, with these directions providing different constraints to the sensorimotor system than the other directions of access.

Ankle evertor muscles play a protective role in ankle injuries. Since the peronoel muscles are known to have a supporting role on the ligaments, the strength of these muscles is important for the support mechanism [70].Despite literature studies rejecting the role of eversion strength deficits as a contributing factor to ankle instability, studies have been conducted to examine the effectiveness of strengthening exercises in ankle instability [106].However, there is no study examining the effect of neuromuscular training on ankle inverter and evertor muscle strength. There is only one study examining the effect of different exercise strategies on ankle evertor and inverter muscle strength. Kaminski et al. investigated the effects of strength and proprioception training on isokinetic strength eversion (E) and inversion (I) ratios in people with unilateral FI. Thirty-eight subjects were assigned at random to one of four treatment groups: strength training, proprioception training, strength and proprioception training, and a control group.The strength group was included in the 6-week plantar flexion, dorsiflexion, inversion and eversion program. The proprioception group received a six-week proprioception training including “T-band kicks”, the 3rd group received treatment that included both training protocols, and the control group did not receive any treatment. As a result of the study, no significant difference was found between the groups in the mean torque and peak torque E/I ratios (30 and 120 °/sn) after training [107].In another study, Docherty et al evaluated isometric dorsiflexor and evertor strengths using a hand-held dynamometer after 6 weeks of resistance theraband exercises. Twenty college students (10 females,10 males: age = 20.6 ± 2.23 years) with functional ankle instability were included in the study. The subjects were allocated to either a training or a control group at random. During the training period, the training group followed a 6-week strength training protocol that included rubber tubing three times per week. The strength training routine was not followed by the control group.At the end of the study, they found that the strength training group had better ankle dorsiflexion, and eversion muscle strength compared to the control group ($p<0.05$) [108].In our study, similar to these studies, we included theraband exercises and calf elevation exercises into strength exercises.We used the Cybex Humac Norm isokinetic dynamometer for ankle inverter and evertor muscle strength measurements.As a result, we saw an increase in strength values at 60 °/sn,120 °/sn and 180 °/sn angular velocities before and after treatment in both groups ($p < 0.05$,Table 4.9), which coincided with their study, but no significant difference was found between the group (Table 4.15).

Proprioception includes the components of joint position sensation, kinesthesia and force sense, and each component can be damaged by an ankle sprain and chronic ankle instability (CAI) is thought to be caused by impaired proprioception [109]. There have been studies in the literature that hypothesize that CAI is associated with impaired mechanoreceptors on the articular surfaces, cutaneous surfaces, ankle lateral ligaments, and joint capsules of the talocrural and subtalar joints [103]. Many studies have been conducted to address proprioceptive deficits in subjects with CAI and to examine the effectiveness of various intervention programs, but there is no study comparing vestibulo-ocular reflex training and neuromuscular training exercise strategies for JPS [106]. Anguish et al., in their study, looked at the effects of two different balance exercise trainings on joint position sense in individuals with chronic ankle instability. Participants were assigned to either the PHSB or the SLB program at random. The PHSB (n=9) and SLB (n=9) groups both completed their four-week programs three times per week. While they found significant differences in pre- and post-treatment values at the end of the 4-week training, they did not find any superiority between the two groups [103]. In another study, Bernier et al. They randomly divided 45 people with functional imbalances into 3 groups. One group was a control group (n=14) and was not included in any treatment program. Second group (n=14) received electrical stimulation to the perenoel brevis and longus muscles as sham treatment. The experimental group (n=17) trained by doing various balance and proprioception exercises for 10 minutes each day, 3 days per week for 6 weeks. The experimental group was given balance and coordination exercise training. At the end of the study, joint position sense and postural sway of the groups were evaluated. They found significant differences in joint position sense in the treatment and control groups before and after treatment. In conclusion, they showed that although coordination training contributed to improvement postural sway in some aspects, it had no significant effect on joint position sense [110]. Similarly,we used the joint position sense parameter to evaluate proprioception and at the end of 4 weeks,we found positive improvements in inversion and eversion joint position sense in the neuromuscular and vestibular ocular reflex exercise group before and after treatment ($p < 0.05$,Table 4.8.).When we compared the two groups after the treatment, although we could not find any superiority to each other, we found that inversion(2.60±1.95,2.20±0.91) and eversion(2.10±1.19, 1.70±1.94) joint position sense errors were less in the vestibulo-ocular group (Table 4.13.).Head movement was included in each of the exercises throughout the 4-week protocol designed to activate the vestibular-ocular reflex in the VOR group, and therefore the differences observed in proprioception may partially explain its contribution to the formation of joint position sense and body awareness in the vestibulo-ocular system.

CAI has been linked to a number of mechanical impairments.One of these mechanical impairment is the limitation of the ankle joint range of motion(ROM). Studies have shown that there are deficits in the ankle dorsiflexion joint range of motion, and this may be connected to the distruption in normal talar arthrokinematics as a result of limitations in non-contractile tissues and degenerative alterations in the ankle complex structure [111]. In the literature, studies examining the effects of neuromuscular and balance training on ankle joint range of motion in people with CAI are limited [112].Lazarou et al. investigated the effects of two different proprioceptive training for 6 weeks on joint range of motion, pain and balance in people with ankle sprains. The study included twenty subjects who were randomly assigned to either a balance (n=10) or a proprioceptive neuromuscular facilitation (PNF) (n=10) group. Over a six-week period, both groups received ten rehabilitation sessions. Dorsiflexion range of motion (ROM), pain, functional and balance performance were evaluated at the beginning, at the end of training, and six weeks after training.As a result of the study, improvement in ankle dorsiflexion joint range was observed in both groups. In the balance group, they found significant ($p < 0.01$) improvements in the frontal plane balance test and pain [113].In another study,Cruz et al. examined the effects of 6-week balance training on chronic ankle instability. A total of 70 athletes were randomly assigned to either the control (n=35) or intervention (n=35) groups. The control group received their regular training, whereas the intervention group had the same activities in addition to a balance training program.Although they did not measure ankle joint range of motion in their study, they said that ankle dorsiflexion joint range of motion could be effective in forward reaching distance in the star excursion balance test. They hypothesized that the moderate improvement in anterior reach distance compared to other directions was influenced by the altered ankle biomechanics and limitations in joint range of motion in people with chronic ankle instability.These studies also showed us that the effect of ankle range of motion on the increase in reach distances should be taken into account in the star excursion balance test [82].Our study is the only study investigating the effect of neuromuscular and combined vestibulo-ocular reflex exercise training on ankle joint range of motion. Similar to other studies, we looked at the goniometric measurement of ankle joint range of motion and at the end of 4 weeks, we found a statistically significant difference in the goniometric measurements of ankle dorsiflexion and plantar flexion on the unstable side in both groups. ($p<0.05$, Table 4.7).While the angle of eversion on the unstable side was significant in the neuromuscular group, there was no significant difference before and after treatment in the vestibulo-ocular group. There was no significant difference in terms of inversion before and after treatment in both groups (Table 4.12.). However, due to the inadequacy of studies conducted in this direction, we could not compare these results with them.

Due to the deficiency of research on incorporating vestibular-ocular reflex training into orthopedic rehabilitation protocols, comparing the findings of our study to those of others is difficult.This is the second study in the literature to include vestibular-ocular reflex (VOR). Unlike the other study, we applied a more extended neuromuscular exercise training protocol and evaluated different parameters. Although there were no limitations in this study and the desired sample size was achieved in the power analysis, the study should be developed in an expanded population and by evaluating the athletes and the general population separately, with improved rehabilitation protocols and long-term follow-up.Further studies are needed to evaluate the long-term effects of vestibulo-ocular reflex training on balance, proprioception and strength in chronic ankle instability.

6.CONCLUSION

In conclusion, this study showed that four weeks of neuromuscular and vestibulo-ocular reflex training significantly improved self-reported function (FAAM), proprioception as determined by joint position sense, dynamic postural control as assessed by SEBT, and isokinetic muscle strength.

Although the two rehabilitation protocols were not found to be superior to each other, we think that the vor protocol is more effective considering the improvements in dynamic postural control and proprioception parameters.

Given the positive results of this randomized clinical trial with a relatively small sample size, further research with CAI patients is warranted with rehabilitation exercises that activate the vestibular-ocular reflex. It is recommended that vestibulo-ocular exercise training should be included in the treatment of people with chronic ankle instability and that more detailed studies should be conducted separately evaluating the population planning to return to sports or work activity.

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8.APPENDIX

Appendix 8.1. Bilgilendirilmiş Onam Formu

Araştırmanın Adı: Kronik Ayak Bileği İnstabilitesi Olan Kişilerde Nöromusküler ve Vestibulo-Oküler Refleks Eğitim Programının Denge ve İzokinetik Kas Kuvveti Üzerine Etkisi

Sayın Katılımcı,

Yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunmaktasınız. Bu araştırmada yer almayı kabul etmeden önce, araştırmanın ne amaçla yapılmak istendiğini anlamanız ve bu bilgilendirme sonucunda kararınızı vermeniz gerekmektedir. Aşağıdaki bilgileri lütfen dikkatlice okuyunuz, sorularınız olursa sorunuz ve açık yanıtlar isteyiniz.

Bu araştırma ile ‘’Ayak bileği instabilitesi olan kişilerde, nöromusküler egzersize ilave olarak verilen vestibülo-oküler refleks eğitiminin denge ve izokinetik kas kuvveti üzerine etkisini karşılaştırmak’’ amaçlanmıştır. Bu araştırma, ulusal ve uluslararası literatüre de katkı sağlayacaktır. Araştırma için Sportomed Sporcu Sağlığı ve Ortopedik Rehabilitasyon kliniğinden izin alınmıştır. Araştırmaya sizin dışınızda 20 kişi katılacaktır. Sizden bu çalışmada ‘’Araştırma kapsamında çalışmaya katılmayı kabul eden gönüllü bireylerin denge düzeyleri,cybex izokinetik dinamometre ile kas kuvvetleri, FADI skalasına göre ayak ve ayak bileği sakatlık endeksi,propriosepsiyon‘’degerlendirilecektir . Birinci gruptan nöromüsküler eğitim ile kombine vestibülo-oküler refleks egzersiz eğitimi, ikinci gruptan nöromüsküler egzersiz yapması istenecektir. Bu işlem 1 buçuk saatinizi alacaktır. Bunun size ve yakınlarınıza hiçbir zararı olmayacaktır. Çalışmaya katılmakla parasal yük altına girmeyeceksiniz ve size de herhangi bir ödeme yapılmayacaktır.

Bu araştırmaya katılıp katılmamakta tümüyle özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Araştırmaya katılmayı istemezseniz burada size verilen hizmet olumlu veya olumsuz şekilde etkilenmeyecektir. Gerekli gördüğü takdirde araştırmanın herhangi bir kısmında katılımcı araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir gizlilik kurallarına uyulmak kaydıyla sunulabilir ve yayınlanabilir.

Araştırma ile ilgili daha fazla bilgiye ihtiyaç duyarsanız araştırmacıya e-posta adresi veya numaralı telefondan ulaşabilirsiniz.

Yukarıda yer alan ve araştırmaya başlanmadan önce katılımcılara verilmesi gereken bilgileri içeren metni okudum (ya da sözlü olarak dinledim). Araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uyulmak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim.

İmza/Tarih	**İmza/Tarih**
Katılımcının adı soyadı	**Sorumlu Araştırmacının adı soyadı:** Prof.Dr.Feryal Subaşı

Appendix 8.2.Etik Onay

T.C.
MARMARA ÜNİVERSİTESİ
Sağlık Bilimleri Fakültesi
Girişimsel Olmayan Klinik Çalışmalar Etik Kurulu

PROJENİN ADI	: "Kronik Ayak Bileği İnstabilitesi Olan Kişilerde Nöromusküler Ve Vestibulo-Oküler Refleks Eğitim Programının Denge Ve İzokinetik Kas Kuvveti Üzerine Etkisi"
PROJENİN YÜRÜTÜCÜSÜ	: Prof. Dr. Feryal SUBAŞI
PROJEDEKİ ARAŞTIRICILAR	: Nilüfer KILIÇ, Dr. Pınar Esra ERDOĞDU
ONAY TARİHİ VE SAYISI	: 27.02.2020/21

Sayın: Prof. Dr. Feryal SUBAŞI

"21" protokol numaralı "Kronik Ayak Bileği İnstabilitesi Olan Kişilerde Nöromusküler Ve Vestibulo-Oküler Refleks Eğitim Programının Denge Ve İzokinetik Kas Kuvveti Üzerine Etkisi" İsimli projeniz Fakültemiz Etik Kurulu tarafından incelenmiş oy birliği ile etik yönden uygun olduğuna karar verilmiştir.

Prof. Dr. M. Gülden POLAT
Etik Kurul Başkanı

Marmara Üniversitesi Sağlık Bilimleri Fakültesi 34854 Başıbüyük/Maltepe /İSTANBUL
0 (216) 399 62 42 (Faks)
0 (216) 777 57 86
Ayrıntılı bilgi için: Melek KARADAĞ AKYOL
sbfetikkurul@gmail.com
http://sbf.marmara.edu.tr

Appendix 8.3. Hasta Bilgi Formu

1.Adınız ve Soyadınız

…………………………………………………………………………

2.Dogum Tarihiniz ……/……./…….

3.Cinsiyetiniz ( )Erkek ( )Kadın

4.Medeni haliniz Evli ( ) Bekar ( ) Dul ( ) Boşanmış ( )

5.Boyunuz (cm) 6.Kilonuz(kg)

7.Vucut Kitle İndeksi(kg/m2)

8.Spora Katılım ( ) Evet ( ) Hayır

9.Yaptıgınız spor

( ) Futbol ( ) Basketbol ( ) Voleybol ( ) Hentbol ( ) Atletizm ( )Tenis ( ) Su topu ( ) Yüzme ( ) Diğer

10.Egitim durumunuz

( )İlkögretim ( )Lise ( ) Lisans ( ) Lisansüstü

11.Sistemik Herhangi bir hastalığınız var mı?

12.Sürekli kullandıgınız bir ilaç var mı?

Adı…………………………………….Dozu………………………………Ne kadar süredir

Adı……………………………………Dozu………………………………Ne kadar süredir

13.Sigara kullanıyor musunuz?

( )Hiç içmedim ( ) içtim,bıraktım ( )halen içiyorum

Kaç yıldır sigara içiyorsunuz? ( ) 10 yıl ( )10 yıldan az ( )10 yıldan fazla

Günde kaç adet sigara içiyorsunuz? ( )1 paketten az ( )1 paket ( )1 paketten fazla

14.Alkol kullanıyor musunuz?

( )Evet ( ) Hayır

15. Herhangi bir ameliyat geçirdiniz mi ?

( )Evet ( ) Hayır

16.Daha önce ayak bileği burkulması geçmişiniz var mı?

( )Evet ( ) Hayır

17.Cevabınız "evet" ise, her bir ayak bileğinizde kaç burkulma oldu?

( )Sağ ( ) Sol

18.Cevabınız "evet" ise, son 6 ay içinde herhangi bir burkulma meydana geldi mi?

( )Evet ( ) Hayır

19.Son altı ay içinde her iki ayak bileğinizde de ''boşalma hissi'' yaşadınız mı?

( )Evet ( ) Hayır

20.Cevabınız evet ise, hangi ayak bileğinde ''boşalma hissi'' yaşadınız?

( )Sağ ( ) Sol ( ) Her ikisi

21.Son 6 ayda ayak bileği burkulması dışında herhangi bir alt ekstremite yaralanmanız oldu mu?

( )Evet ( ) Hayır

Appendix 8.4.Değerlendirme Formu

Ad: Soyad:

AYAK BİLEĞİ EKLEM HAREKET AÇIKLIĞI

AYAKBİLEĞİ	**SAĞ**	**SOL**
DORSIFLEXION		
PLANTARFLEXION		
INVERSION		
EVERSION		

PROPRİOSEPSİYON

AYAKBİLEĞİ	**SAĞ**	**SOL**
EVERSİYON (10°)		
İNVERSİYON (20°)		

YILDIZ DENGE TESTİ

	SAĞ	**SOL**
ANTERIOR		
POSTERIOR		
ANTEROMEDIAL		
ANTEROLATERAL		
MEDIAL		
LATERAL		
POSTEROMEDIAL		
POSTEROLATERAL		

İZOKİNETİK KAS KUVVETİ

30 °inversiyon 20° eversiyon limitli 60°/sn -6 tekrar ;120°/sn-6 tekrar;180 °/sn-20 tekrar

Appendix 8.5.Ayak ve Ayak Bileği Kullanılabilirlik Ölçüsü

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	Yapamıyo-rum	Uygulana-maz
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	Yapamıyo-rum	Uygulana-maz
Ev işleri	☐	☐	☐	☐	☐	☐
Günlük yaşam aktiviteler	☐	☐	☐	☐	☐	☐
Kişisel bakim	☐	☐	☐	☐	☐	☐
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	Yapamıyo-rum	Uygulana-maz
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

Appendix 8.6.Özgeçmiş

Kişisel Bilgiler

Adı	Nilüfer	**Soyadı**	KILIÇ CERBEZER
Doğum Yeri		**Doğum Tarihi**	
Uyruğu		**TC Kimlik No**	
E-mail		**Tel**	

Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora			
Yüksek Lisans			
Lisans	FTR	Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi	2017
Lise	Sayısal	Merzifon Anadolu Lisesi	2011

Başarılmış birden fazla sınav varsa(KPDS, ÜDS, TOEFL; EELTS vs), tüm sonuçlar yazılmalıdır

Bildiği Yabancı Dilleri	Yabancı Dil Sınav Notu (#)
İngilizce	

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	Süre (Yıl - Yıl)
Fizyoterapist	Sportomed	2018-
Fizyoterapist	Pt Akademi	2017-2018
Fizyoterapist	Prof.Dr.Yavuz Kocabey Klinik	2017-2018

Bilgisayar Bilgisi

Program	Kullanma becerisi
Microsoft Office	İyi
SPSS	İyi

***Çok iyi, iyi, orta, zayıf olarak değerlendirin**

Bilimsel Çalışmaları

SCI, SSCI, AHCI indekslerine giren dergilerde yayınlanan makaleler

Diğer dergilerde yayınlanan makaleler

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

Hakemli konferans/sempozyumların bildiri kitaplarında yer alan yayınlar

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)