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YEDİTEPE UNIVERSITY

INSTITUTE OF HEALTH SCIENCES

DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

EXAMINATION OF UNIVERSITY LEVEL VOLLEYBALL PLAYERS IN TERMS OF ANKLE FUNCTIONS AND POSTURAL CONTROL VARIABLES

MASTER THESIS

Ayşem Ecem ÖZDEMİR, PT.

İSTANBUL-2023

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APPROVAL

This thesis has been deemed by the jury in accordance with the relevant articles of Yeditepe University Graduate Education and Examinations Regulation and has been approved by Administrative Board of Institute with decision dated 11.02.2022 and numbered 202202159.

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.

Ayşem Ecem ÖZDEMİR

DEDICATION

I would like to dedicate my thesis to my mother, father and brother, who have loved and supported me without expecting anything in return, and also to my grandmother, who I wish could have seen my success.

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LIST OF SYMBOLS AND ABBREVIATIONS

AP	Anterior-Posterior
API	Anterior-Posterior Instability
ATL	Anterior Talofibular Ligament
BM	Basınç Merkezi
BMC	Body Mass Center
BMI	Body Mass Index
BoS	Base of Support
CAIT	Cumberland Ankle Instability Tool
CFL	Calcaneofibular Ligament
CG	Control Group
CoG	Center of Gravity
CoP	Center of Pressure
DF	Dorsiflexion
EG	Experimental Group
EHA	Eklem Hareket Açıklığı
EPH	Eklem Pozisyon Hissi
EVR	Eversion
INVR	Inversion
JPS	Joint Position Sense
KG	Kontrol Grubu
LCL	Lateral Collateral Ligament

MCL	Medial Collateral Ligament
ML	Medial-lateral
MLI	Medial-Lateral Instability
NCAA	National Collegiate Athletic Association
OSI	Overall Stability Index
PF	Plantar Flexion
PTL	Posterior Talofibular Ligament
ROM	Range of Motion
SD	Standard Deviation
SUPN	Supination
VG	Voleybol Grubu (Türkçe)
VG	Volleyball Group (English)

ABSTRACT

Özdemir, A. E. (2023). Examination of University Level Volleyball Players In Terms of Ankle Functions and Postural Control Variables. Yeditepe University, Institute of Health Sciences, Department of Physiotherapy and Rehabilitation, Master Thesis. Istanbul.

Ankle functions and postural control ability have great importance to understand the skills for the sport of volleyball. **Purpose:** The aim of the study was to examine different ankle functions and postural stability variables of volleyball players and healthy students. **Method:** The participants (21.18 ± 1.76 year olds, F, n=40) included in the study were divided into two groups as volleyball (VG; n=20) and control (CG; n=20). Postural control variables (sway velocity, area of displacement and perimeter) was evaluated by static stability test (PK Prokin 252 stabiliometer). Ankle range of motion (ROM), joint position sense (JPS), vibration and strength measurements were evaluated. The Independent Sample T-test, Mann Whitney U test, and the Spearman Correlation Coefficient was used for statistical analysis. **Results:** Between the groups, significant differences were observed in dorsiflexion, eversion and inversion ROM, JPS, vibration sense in the 1^{st} and 5^{th} toe, dorsiflexor and plantar flexor isometric muscle strength and postural stability variables ($p<0.05$). The sway velocity was correlated with dorsiflexion ROM and invertion isometric muscle strength, the perimeter with eversion ROM, JPS at the 130° and 140° of ankle and vibration sense from the forefoot ($p<0.05$). The area of displacement was correlated with eversion ROM, dorsiflexor and evertor isometric muscle strength ($p<0.05$). **Conclusion:** Volleyball players have different ankle functions and better postural stability than healthy controls. Postural stability variables have been shown to be correlated with ankle functions. The examination of postural stability variables in athletes may be a marker in preventing sports-specific ankle injuries.

Keywords: Volleyball, Postural Control, Ankle Joint

ÖZET

Özdemir, A. E. (2023) Üniversite Düzeyindeki Voleybolcuların Ayak Bileği Fonksiyonları ve Postüral Kontrol Değişkenleri Yönünden İncelenmesi. Yeditepe Üniversitesi, Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon ABD., Yüksek Lisans Tezi. İstanbul.

Voleybol sporuna yönelik becerilerin anlaşılmasında ayak bileği fonksiyonları ve postüral kontrol yeteneği büyük önem taşımaktadır. **Amaç:** Bu çalışmanın amacı voleybolcular ve sağlıklı öğrencilerin farklı ayak bileği fonksiyonlarını ve postüral stabilite değişkenlerini incelemektir. **Yöntem:** Çalışmaya alınan katılımcılar (21,18 ± 1,76 yaş, K, n=40) voleybol (VG; n=20) ve kontrol (CG; n=20) olmak üzere iki gruba ayrıldı. Postüral kontrol değişkenleri (salınım hızı, yer değiştirme alanı ve çevre) statik stabilite testi (PK Prokin 252 stabiliometre) ile değerlendirildi. Ayak bileği eklem hareket açıklığı (EHA), eklem pozisyon duyusu (EPH), vibrasyon ve kuvvet ölçümleri değerlendirildi. İstatistiksel analiz için Bağımsız Değişken T-testi, Mann Whitney U testi ve Spearman Korelasyon Katsayısı kullanıldı. **Bulgular:** VG'da dorsifleksiyon, eversiyon ve inversiyon EHA, JPS, 1. ve 5. parmaklarda vibrasyon duyusu, dorsifleksör ve plantar fleksör izometrik kas kuvveti ve postural stabilite değişkenlerinde anlamlı fark gözlendi ($p<0.05$). Salınım hızı, dorsifleksiyon EHA ve inversiyon izometrik kas kuvveti ile, perimetre ile eversiyon EHA, ayak bileğinin 130° ve 140°'sindeki EPH ve ön ayaktan vibrasyon duyusu ile ilişkiliydi ($p<0.05$). Yer değiştirme alanı, eversiyon EHA, dorsifleksör ve evertor izometrik kas kuvveti ile ilişkiliydi ($p<0.05$). **Sonuç:** Voleybol oyuncuları, sağlıklı kontrollere göre farklı ayak bileği fonksiyonlarına ve daha iyi postural stabiliteye sahiptir. Postural stabilite değişkenlerinin ayak bileği fonksiyonları ile ilişkili olduğu gösterilmiştir. Sporcularda postural stabilite değişkenlerinin incelenmesi spora özgü ayak bileği yaralanmalarını önlemede bir belirteç olabilir.

Anahtar Kelimeler: Voleybol, Postural Kontrol, Ayak Bileği Eklemi

1. INTRODUCTION AND PURPOSE

Postural control is achieved by the formation of the necessary motor response after the sensory afferent inputs (proprioceptive, vestibular and visual) coming from the inner and outer regions reach the upper centers and are processed (1). There are studies proving that the risk of injury to the ankle and knee regions is higher in athletes with poor postural control compared to those with normal postural control (2–4). These studies prove the importance of providing postural control in order to prevent sports-specific injuries.

Volleyball is a sport consisting of successive and rapidly changing movements. Adapting to these postural changes is important for the continuity of the game. Adaptation to the dynamic mechanism inherent in volleyball occurs in direct proportion to the athlete's level of postural control (5). Balanced stance and effective postural control in activities involving ball contact during the game are the basic skills of volleyball (6).

Ankle functions and postural control ability have an important place in volleyball. The ankle joint creates a dynamic link between the body and the ground (7). The ability to adapt to different positions and movements created by this bond is directly related to postural control. The ankle is a joint that needs to be evaluated frequently and its functions should be improved both in order to improve postural control ability and to prevent possible injuries. It has been proven in studies that the capacity shown in different functional parameters such as joint range of motion (ROM), strength and proprioception, and balance all reduces the risk of injury and positively reflects on the performance parameters of the athlete (8–10).

In the literature, there are studies on different ankle functions and dynamic and/or static balance abilities of athletes with ankle pathologies (functional ankle instability and ankle sprain) (11–13). They compared the effect of altered ankle functions on static or dynamic balance abilities after pathology occurred, with healthy controls. It has been proven in these studies that athletes with ankle injuries are more unsuccessful in balance tests than healthy ones. Postural controls of healthy volleyball players and their controls have also been evaluated in different studies, but ankle function assessments were not included in the content (1,6,14).

It is useful to evaluate and examine the ankle functions and postural control abilities that change as a result of the training and exercises performed by the athletes, unlike healthy individuals who are not athletes, in order to understand the abilities developed specifically for the sport.

The aim of this study, which was designed as an observational case-control study, was to examine different ankle functions and postural control variables in university level volleyball players with stable ankles and to compare the data with healthy controls. We believe that our study will contribute to the literature, congress presentations, and exercise and rehabilitation programs to be created by physiotherapists interested in athlete health.

The hypothesis set in this study are:

H0: There is no difference between ankle functions and postural control variables of volleyball players and healthy controls.

H1: There is a difference between ankle functions and postural control variables of volleyball players and healthy controls.

2. GENERAL INFROMATION

2.1. Postural Control

Postural control is defined as reaching or regaining a state of balance during quiet stance or movement (15). Sensory and motor systems operate with complex connection pathways to activate the postural control system (16). Postural control is maintained by ensuring the balance that needs to be achieved with environmental factors, as well as by providing the intrinsic balance (17).

Physiological postural sway is defined as corrective movements in the body's center of gravity (CoG) to provide postural control in static upright posture (18). The formation of the necessary responses is provided by the transmission of postural changes and changes in body oscillation to the upper centers and the integration of these notifications. The postural control system interacts with both sensory (visual, vestibular, somatosensory), motor and nervous systems in order to provide and maintain balance (Figure 1) (19).

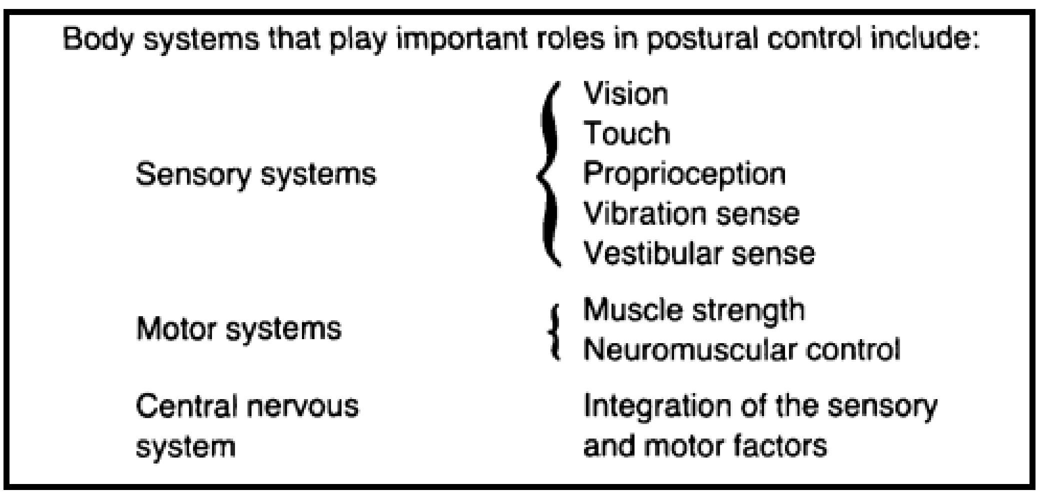

Figure 1: Model of Postural Control (19).

2.1.1. Postural control types

In silent upright stance, several different postural control types come into play to compensate for the possible destabilizing situations (20). It functions as a feedback control circuit between the brain and the musculoskeletal system. Static, adaptive, reactive and proactive postural control types have been studied across literature (21).

Static type is the state of postural control in which the body mass center (BMC) is controlled while standing upright, above the existing support surface which is the base of support (BoS). Even if the net force on the object is zero, oscillations of the object occur and actually this turns out to be a dynamic process.

Adaptive postural control, is a type of postural control which is used to maintain the body position during voluntary movements or changes in the outside world.

Reactive type occurs when the responses created in the face of possible movement changes at sudden, unexpected moments like walking over a pit that suddenly appears while walking on the sidewalk. Different strategies are used to compensate these sudden changes.

Whereas proactive type is state of making the system suitable for the conditions that may occur before the foreseen situation and making the necessary preparations in order to compensate for the possible instability. It involves the ability to mobilize the necessary postural muscles before the condition occurs (18).

2.1.2. Postural control systems

The sensory system (visual, vestibular, somatosensory), the musculoskeletal system and the central nervous system are the systems responsible from postural control. In order to create the compensations mentioned in postural control types, these three systems must work in an integrated manner. If problems occur in even one of these systems, the postural control mechanism will be interrupted and problems might come to life.

The visual system provides information about the position of the head and the movement that will occur by referencing the surrounding objects. During silent stance, postural control can be maintained without visual input, but this will cause a large increase in swinging motion (22).

The vestibular system perceives the linear and angular position of the head and movement in space, while it provides tone regulation of the skeletal muscles during posture and movement, which assures integration of balance and orientation through vestibular reflexes (23,24)

Because somatosensory receptors give information about the movement and position of the extremities and the tension of the target postural muscles, they contribute to postural control. This system encompasses all mechanical and sensory information coming from the environment like pain, temperature, touch, and proprioception.

Muscle spindle and golgi tendon organ, which are proprioceptive receptors, are involved in motor control. Proprioceptive receptors in muscles and tendons send signals to change the length of the muscle through the postural control system (25). The muscle spindle is responsible for the muscle stretch reflex, which informs the upper centers about the changes in the length of the muscle fibers via the 1a and 2 afferents, and stimulates the alpha motor neuron, after which muscle contraction occurs (26). The golgi tendon organ, on the other hand, is sensitive to the tension of the contracted muscle and transmits information to the upper centers with 1b afferents, so that the inhibition of the alpha motor neuron takes place in the upper centers (27).

The nervous system has an idea about BMC thanks to the information and inputs from the sensory systems while the planning role is a responsibility of the brain. After the necessary plan is created accordingly to the inputs from sensory systems, the outputs are transmitted to the units of musculoskeletal system, by pyramidal and extrapyramidal systems. These outputs in cortical motor areas; are transmitted in connection with the cerebellum, reticular formation and basal ganglia (16). Basal ganglia are the structures responsible for the control of reflex and voluntary movements (28). The structure responsible for static and rhythmic muscle activity and limb movements is the cerebellum and it contains three layers which are responsible of these motor functions. The reticular formation, on the other hand, creates the necessary networks and connections of the centers working to provide postural control (29). So after all of these process, the ability to maintain postural balance occurs which can be seen at Figure 1 (30).

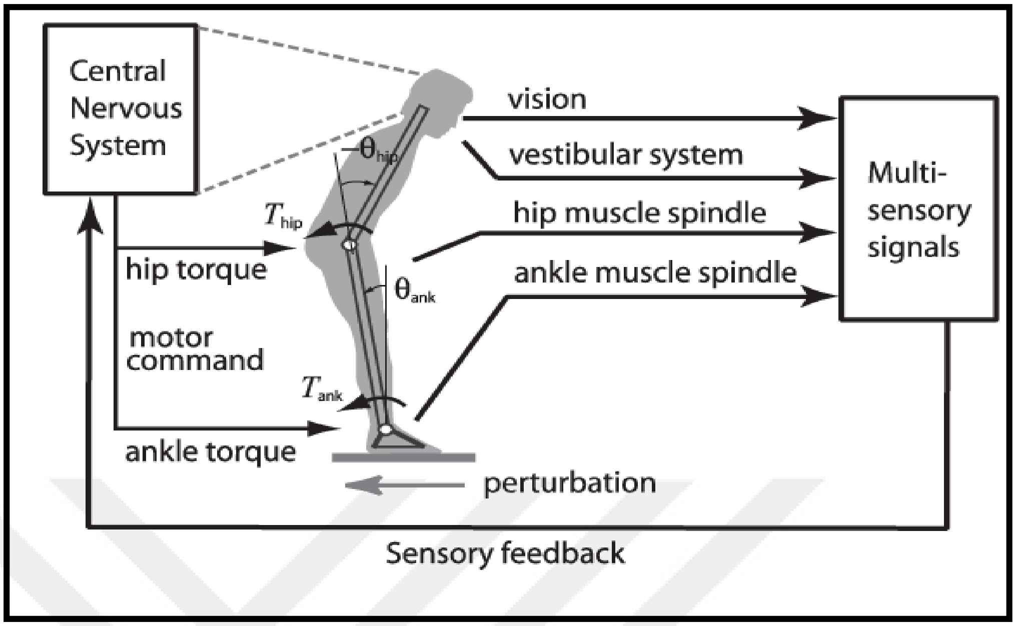

Figure 2: Postural control loop driven by the CNS (30).

2.1.3. Postural control strategies

The use of existing strategies is related to the configuration of the BoS and the severity of external or internal perturbations. Most of the oscillations that occur in sitting and standing positions, which occur frequently in daily life, occur in the anterior-posterior (AP) directions (31). These strategies help prevent falling and occur unconsciously. There are three different strategies to achieve AP stability, which are ankle, hip and stepping strategy (Figure 2) (32).

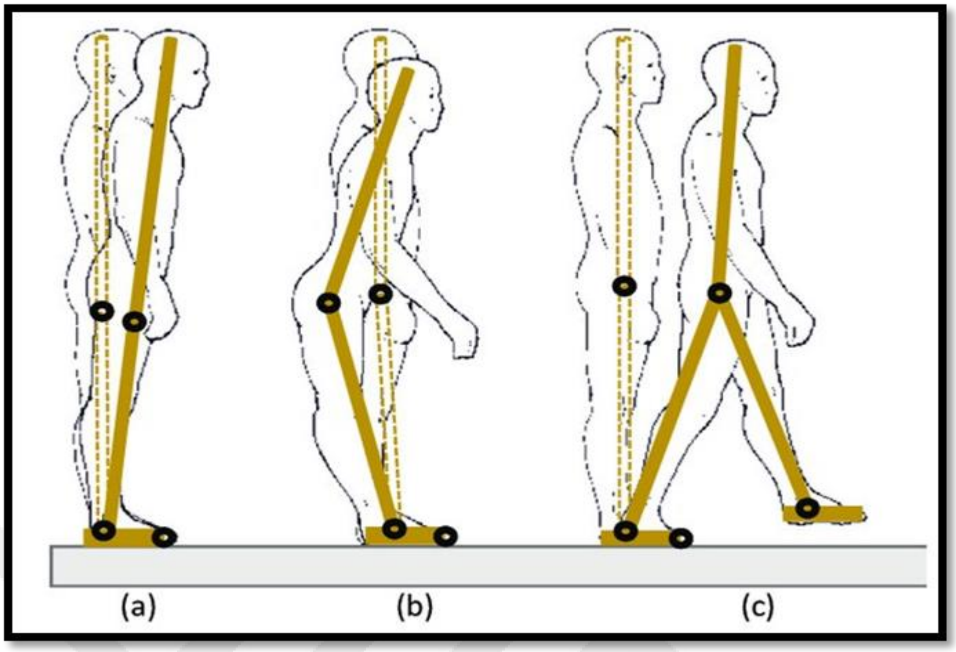

Figure 3: The postural control strategies used to compensate the anterior-posterior displacements of BMC. a) ankle strategy b) hip strategy c) stepping strategy (32).

Ankle Strategy: The most common motion strategy developed against AP perturbations is the ankle. This strategy aims to change the position of the BMC by moving the trunk around the ankle joint, with minimal contributions from the hip and knee joints, which are other lower extremity joints contributing to ankle strategy. Implementation of the ankle strategy requires optimal ROM and strength of the ankle. It acts as a single-segment inverted pendulum and repositions the BMC, while generating sufficient torque from the entire body from the ankle (31).

The ankle strategy is robust enough to withstand rotational movements and forces and is activated when low-intensity perturbations occur (33). The perturbations that the individual encounters in the posterior direction cause the individual to move forward, therefore, when the center of gravity shifts backwards, activation is primarily observed in the anterior group muscles (34). The ankle strategy continues with the activation of the dorsal hip and para spinal muscles. After the dorsal region, contractions continue in the plantar flexor muscles and then spread from distal to proximal. It was shown that, the ankle joint is used more than the hip and knee joints when controlling balance in quiet upright posture and when there is little movement and when these minor perturbations occur, the major muscle groups involved are the ankle flexor/extansors and invertor/evertors (35,36).

Hip Strategy: When exposed to perturbations of higher severity, regulation at hip level becomes more effective rather than ankle (37). The primary activated muscles are the ones which are around the hip joint. It was observed that the ankle muscles were activated at lower rates after the muscles in the thigh and trunk, which were necessary for the strategy, were activated (Figure 3) (38). Kinematic analyzes show that when trunk flexion occurs, extension movement is observed in the ankle (39). Also, the hip strategy requires lower levels of muscle activation than the ankle strategy in order to maintain the same rate of displacement of the BMC on plain grounds (40).

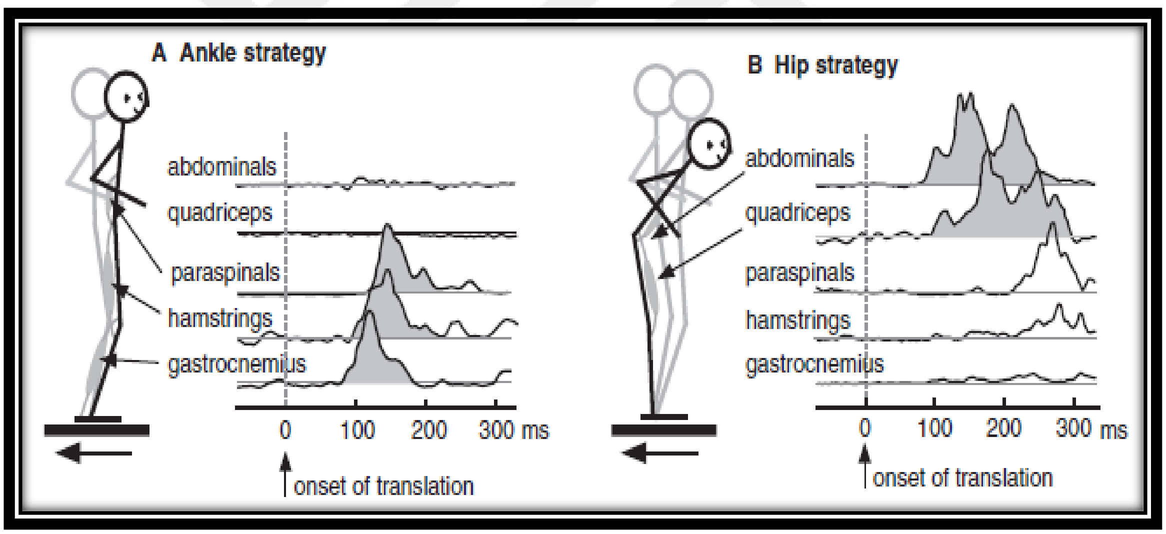

Figure 4: Muscles involved in ankle and hip strategies and firing times after posterior perturbation of the support surface (38).

Stepping Strategy: The stepping strategy is used against the high severity perturbations which the other strategies cannot compensate. The main idea of this strategy is that, when the perturbation occurs, to widen the BoS, the lower extremity is used for stepping. This way the compensation of larger displacements of BMC can be achieved (41).

2.1.4. Factors effecting postural control

There are many factors that are effecting the postural control ability. Some factors like height, weight, the location of the CoG and BoS have been reported and still ongoing researches are done (42). In a study increased body mass index (BMI) was found to be positively associated with postural control whereas the other found an negative correlation (43). Another factor; aging, is a factor affecting for postural control because by aging the need of attentional demands to alter stability increases while sensory integrations slows down (44).

Not just demographic variables but also physical fitness parameters affect postural control ability. Muscle strength and endurance skills of back group muscles are found to have an relationship with postural stability results (43). Also back muscle fatigue is found to have alterations when it comes to center of pressure (CoP) displacement velocity (45). Because the lower extremity plays an important role for postural control, the importance has been searched widely. Some muscle groups have a duty in the postural control strategies so the strength and mobility of the joints and surrounding soft tissues are of great importance. The muscle strength of lower extremity muscles and plantar flexion passive ROM are some parameters affecting static balance control ability (46).

Rather than being a part of the motor control system, there are two different roles of proprioception. First one is the role which proprioception is needed for the regulations that occurs from the external environment. When external perturbations occur, the mechanoreceptors of the target area, will convey the information about the changes in the joint position and prepare the ground for possible alterations that will come to life for ensuring postural control. The second role of proprioception is that; it not just provides information from the external environment but also is responsible for the information coming from the internal environments. When the perturbation occurs, the needed answer is given when the proprioceptive information coming from the musculoskeletal system is received and the proper planning is made when the current situations of the components of the musculoskeletal system is received so that postural control can be achieved.

The somatosensory system greatly contributes to the postural control system by providing information about position and movement from each part of the body (18). A factor affecting postural control is the vibration sense, which is a part of the somatosensory system. When the loss of sensory information happens at the lower limbs, postural control is negatively affected (47). The body sway increases when the somatosensory information decreases.

2.2. Anatomy of Foot and Ankle

2.2.1. Foot bones

There are 26 bones in the foot. There are a total of 33 joint structures in the foot and ankle complex together with the leg bones (48). Of the bones in the foot, 7 are tarsal bones, 5 are metatarsal bones, and the other 14 are phalanxes. The foot is functionally divided into 3 as rearfoot, midfoot and forefoot. Rearfoot; consists of the talus and calcaneus. Midfoot; consists of the remaining tarsal bones, the navicular, cuboid, and cuneiforms. Forefoot; consists of metatarsals and phalanges (Figure 4) (49).

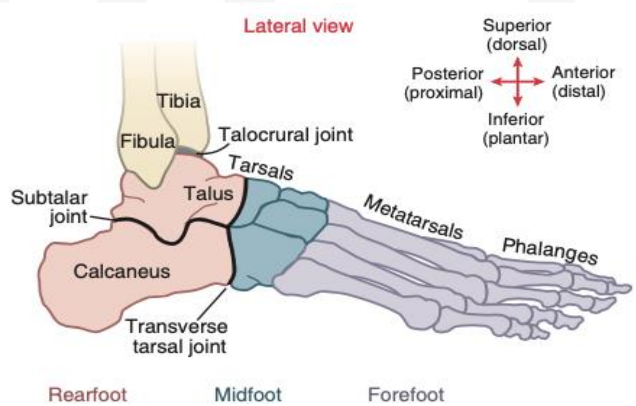

Figure 5: Regions of the foot and ankle (49).

2.2.2. Foot and ankle joints

The distal tibiofibular joint consists of the articulation of the tibia medially and the fibula laterally, and is a syndesmosis type joint. The fibula continues distally as the lateral melleol and the tibia as the medial malleolus (50). The talocural joint is a hinge type joint formed between the talus and the distal tibia and fibula. The subtalar joint is formed between the posterior medial and anterior facets of the talus and calcaneus, which are the hindfoot bones.

2.2.3. Ligaments of ankle joint

Anterior tibiofibular, posterior tibiofibular ligament and interosseours membrane or ligament, which are syndesmotic ligaments of the distal tibiofibular joint; provides stability between the distal tibia and fibula and protects the unity of the tibia and fibula against the external forces exposed (50).

The medial collateral ligaments (MCL), also called the deltoid ligament, start from the medial malleolus and extend to the tarsal bones (51). They limit the eversion (EVR) movement of the talocrural, subtalar and talonavicular joints and protect them from valgus stress (49). MCL; consists of the anterior and posterior tibiotalar ligaments, the tibionavicular ligament and the tibiocalcaneal ligament (Figure 5) (52). The lateral compartment includes the anterior talofibular (ATFL), posterior talofibular (PTFL), and calcaneofibular (CFL) ligaments, which are the lateral collateral ligaments (LCL). LCL occurs with mechanism of injury inversion (INVR) injuries. ATFL is injured by plantar flexion (PF) and INVR , PTFL is accompanied by dorsiflexion (DF) and INVR, and CFL is injured by INVR movement in the neutral position of the foot (49).

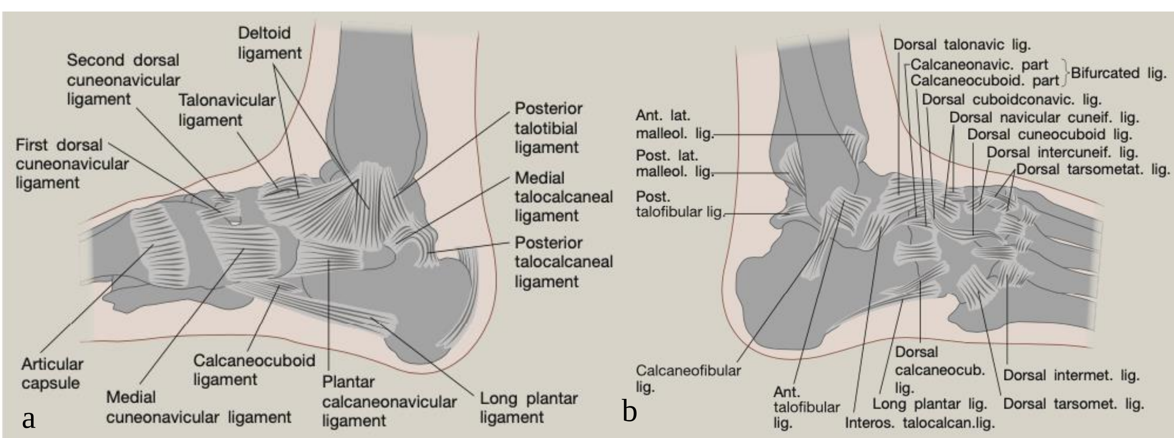

Figure 6: a) Medial compartment ligaments of the ankle joint b) Lateral compartment ligaments of the ankle joint (52)

The main connection between talus and calcaneus at the subtalar joint is provided by a strong ligament, which is the interosseous talocalcaneal ligament. The other two ligaments involved in the connection are the lateral talocalcaneal ligament and the anterior talocalcaneal ligament. The subtalar joint is also supported by the CFL and the tibiocalcaneal ligament (48,53).

2.2.4. Ankle joint muscles and biomechanics

Extrinsic Anterior Compartment Muscles

Anterior compartment muscles; consists of tibialis anterior, extensor digitorum longus, extensor hallucis longus and peroneus tertius, and these muscles are the muscles that create DF movement (Figure 6) (54). They ensure that the contact of the foot with the ground is cut off during the swing phase of the gait. In the stance phase, it works eccentrically and controls the PF movement after the heel strike (7).

The tibialis anterior acts as the largest and strongest ankle dorsiflexor. It also reveals supination (SUPN) and INV movement with DF and is stimulated by nervous peronuos profundus. Starting from the proximal lateral surface of the tibia, it attaches to the base of the 1st metatarsal bone (52). While the Extensor Hallusis Longus helps the formation of DF moment in the foot by folding the ankle, the Extensor digitorum longus muscle folds the subtalar joint from the lateral and helps to create the INVR moment in the foot (55).

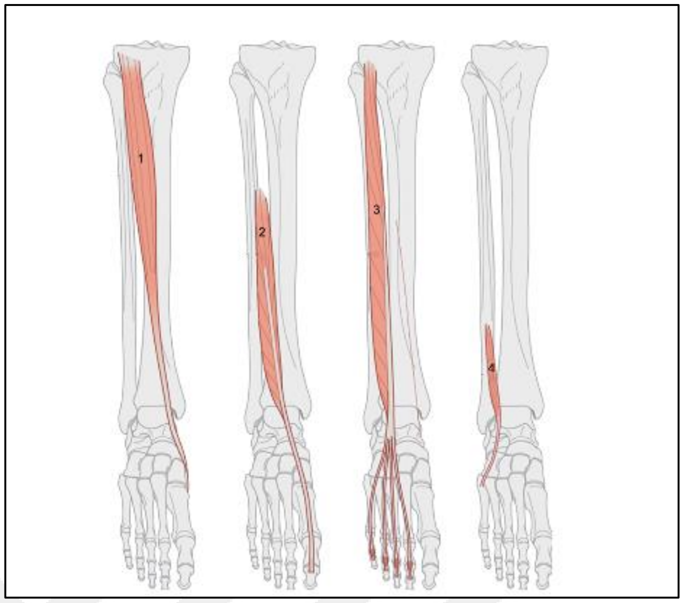

Figure 7: Anterior Extrinsic muscles; 1) Tibialis Anterior, 2) Extensor Hallucis Longus, 3)Extensor Digitorum Longus, 4) Peroneus Tertius (54).

Extrinsic Lateral Compartment Muscles

Peroneus longus and brevis, which are the lateral compartment muscles, reveal 65% of the PF and EVR motion in the ankle and are stimulated by the Nervous peroneus superficialis (Figure 7) (54). Peroneus longus, which is an important stabilizer of the ankle, starts from the caput fibula and passes behind the lateral malleolus and attaches to the base of the first metatarsal bone (56). Peroneus brevis, on the other hand, starts from two-thirds of the surface of the fibula distally, passes posterior to the lateral malleolus and attaches to the styloid process of the 5th metatarsal (52).

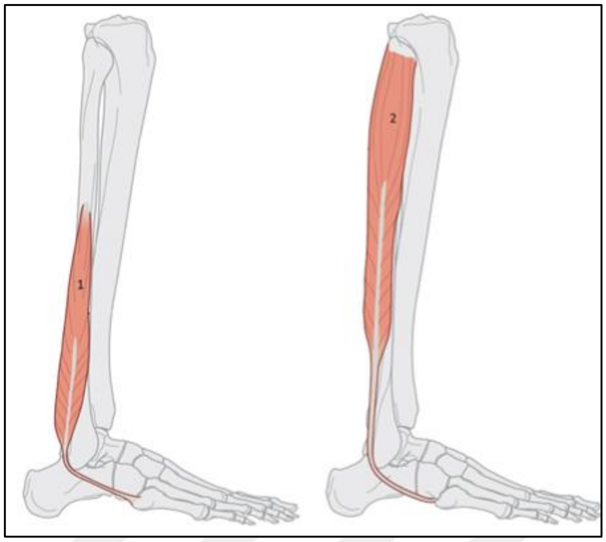

Figure 8: Anterior Extrinsic muscles; 1) Peronous Brevis, 2) Peroneus Longus (54).

Extrinsic Posterior Compartment Muscles

Posterior compartment muscles are divided into deep and superficial. The gastrocnemius, soleus and plantaris from the superficial compartment together form the triceps surae. Triceps surae constitutes higher than 60% of the total PF moment (54). In the deep part, there are Tibialis posterior, Flexor digitorum longus and Flexor hallucis longus responsible for the PF and INVR moment. All posterior compartment muscles are stimulated by the nervous Tibialis.

Gastrocinemius has a two-headed structure as lateral and medial. The lateral head originates from the lateral condyle and the medial head originates from the medial condyle. The medial head is shorter than the lateral head. The abdominals of the muscles extend towards the middle parts of the calf and form a tendinous structure that accompanies the aponeurosis. To form the Achilles tendon, they fuse with the tendon of the soleus muscle, which is responsible for creating a significant PF moment, and the Achilles tendon attaches to the posterior surface of the calcaneus (57). It serves as the main plantar flexor of the ankle and plays a major role in the pushing phase of gait. At the same time, it helps the formation of flexor moment in the knee (55). The plantaris originates from the lateral supracondylar area of the femur and attaches to the posterior calcaneus by joining the Achilles tendon. The plantaris muscle, which is sometimes absent in humans and is proprioceptively important, is generally used for tendon transfers (58).

Tibialis Posterior, which is one of the deep compartment muscles, starts from the posterior proximal tibia, then passes through the posterior of the medial malleolus and attaches to the tarsal bones. Thanks to the moment arm it creates, it provides INVR movement and also dynamic stabilization of rarefoot in walking.

2.3. Ankle Joint Stability

Stability is the resistance given to movements when the joint is exposed to load. Passive stability, which is defined as the measure of the limitation created by any anatomical structure, reflects the mechanical properties of these structures as well as being shaped within the framework of the interactions between the joints and soft tissues and the integrity of these structures with each other. On the other hand, active stability is defined as the response of the mechanical interactions of the soft tissue and joint surfaces to the forces created by gravity (59).

Because the ankle is located near the base of support points of the body, the stability of the ankle joint plays a highly important role to avoid possible injuries. It is proven that mechanical and functional instability causes ankle sprains (60). By an ankle sprain the static stabilizers which are the ligaments of the ankle joint are being damaged and this will lead to irregular joint mechanics which can cause mobility problems or instability by changing the neuromuscular functions (61). So, to know which factors are effecting ankle stability is important for protection from an injury.

2.3.1. Factors effecting ankle joint stability

To ensure joint stability, both mechanical and neural mechanisms contribute to keep the actual movement within normal anatomical limits. The mechanical mechanism provides static restriction to the excessive joint movement of the static structures around the joint. In another hand, the neural proprioceptive mechanisms contribute to maintain joint stability by providing neuromuscular control (62).

There are many factors that are affecting ankle joint stability. Deviation of any of the existing factors from the normal pose a risk for instability. In fact, the same factors are also affected by the presence of instability as well.

There are two types of risk factors that are affecting joint stability; intrinsic and extrinsic. Age, sex, body composition, muscular strength, postural balance, history of injury and also additional to these, joint anatomy and psychological factors are accepted as intrinsic risk factors (63). Extrinsic factors are the ones which the sport causes like, shoe preference or court type.

The variables which are affecting ankle stabilization are still being investigated by the researchers but there are also useful sources about these factors which have been transferred from past to present. The effects of joint mobility, deep sense and muscle strength variables on ankle stabilization have been investigated in the literature. Therefore, examining and developing these variables in highly active populations are of great importance for injury prevention.

2.3.1.1. Ankle joint mobility

Joint mobility is the ability and capability of the joint in regarding movements. Ankle joint mobility is essential not just for normal gait but also for participation to sports and physical activities. Due to the rapidly changing dynamic structure of volleyball; adequate mobility is essential to achieve the required ranges of motion and proper joint mechanics. While jumping and landing which are the building blocks of the game, and also are accompanied by rapid direction changes, the presence of insufficient mobility increases the risk of injury (64).

Higher EVR ROM is found to be a risk for injury (65). Also decreased active DF ROM is found to be a predictor for ankle injuries among volleyball players because lower DF ROM in the ankle joint can cause stiff landing after jumping, which increases the risk of ankle sprains (8,64). It is hard to conclude in average joint mobility or flexibility values but, persons with inflexible ankles are at five times higher risk for enduring ankle injuries than the ones who are close to average flexibility (66).

2.3.1.2. Deep sense

Because joint stability depends on sensory input from peripheral receptors and other feedback mechanisms, they are highly significant factors for the maintenance of joint stability (62). In order to provide neuromuscular control and joint stabilization; sensory inputs from the somatosensory, vestibular and visual systems are processed through the central nervous system.

Somatosensory function is provided by senses such as vibration, pressure and temperature which are perceived by mechanoreceptors (67). The processed information coming from the ankle joint, is essential for conscious and unconscious sense of joint position and stabilization as well as postural control and balance (68,69). Throughout this process: proprioceptive receptors give an idea about the position of the extremities and the tension of the postural muscles during silent stance. Sensorimotor control contributes to the entire flow of information from and to the periphery and the center, as well as joint stability and acts as a building block for central integration (70).

Researches are showing that better JPS results may decrease the risk of a possible ankle injury (71). Injured patients have higher deviations from average values for error sensing for passive INVR, which resulted as a risk factor for inversion injuries (72). Not just injury prevention, but also improved ankle JPS among other joints, is the most significant predictor of performance parameters for athletes (10).

2.3.1.3. Muscle strength

Another factor affecting ankle stability is muscle strength. Muscle strength have been found to be a contributing factor for joint stability. This means that, the greater the strength of a specific muscle gets, the easier the stability of the joint will be provided (62). Not just improvement of the strength, but also the different strength capabilities of antagonistic muscle groups are important to ensure stability (60).

A disproportionate increase in muscle strength can also sometimes cause negative affects to the stability mechanism. When the muscles perform co-contraction in a proper way, they provide the necessary coordination and this ensures joint stability while protecting possible injuries (73).

Ankle evertor muscles, supports the ligaments which are linked to the joint, so the strength of these muscles is a factor to ensure joint stability (72). In a prospective study, it is found to be that the group which have ankle injuries has an increased averaged ratio between evertor and invertor muscles (1.0) than the uninjured ones (0.8) (65). Also it is reported that, differences in strength of dorsiflexor and plantar flexor muscle groups between limbs, is higher in the group which had injuries after baseline evaluations (8,65). Among volleyball players, increased PF muscle peak torque is found to be a predictor of ankle sprains, which occurs as a risk factor (8).

2.4. Volleyball

Volleyball is a sport played as a team. The opposing teams are divided by a set. In each team, 6 players compete. Each player has different positions and duties on the field. Because the role of each position is different, the physical characteristics and sport-specific abilities of all players are different as well. A setter is supposed to pass the ball to the hitters and organizes the attack. Hitters (outside and middle) are the ones who attack to the opposing team by spiking the ball. The ones who are playing in front of the net, blocks the opposite teams spike by jumping. To score a point, the ball should touch the ground of the opposing teams side. The libero is the key person for defense. Normally, they are the shortest in the team and they wear different colored uniforms.

A volleyball match is finished when a team wins 3 sets and to win a set, the team should score 25 points before the other team. If both team scores 24 points, the point to win the set increases 2 points. If both opposing teams win 2 sets, to win the last set the teams should score 16 points.

2.4.1. Injuries in volleyball

Types of injuries differ depending on the positions the players play. Since volleyball is a non-contact sport, serious injuries are rare (7). Mostly the injuries are seen in preseason period rather than regular season or postseason period (74). The most common acute injuries in volleyball players are ankle sprains and concussions, overuse injuries are patellar tendinitis and shoulder tendinitis, and serious knee ligament injuries are rarely encountered in volleyball sport (7). Overuse injuries are more common because of repetitive movements, wrong techniques or playing surfaces (75).

According to the position played, most injuries were reported from outside hitters (27.5%) and secondly from middle hitters (21.8%) (74). Volleyball injuries are usually seen during or after the block, during jumping or landing phase which are volleyball-specific tasks (2). Injuries are most common in the descending phase after the block (76).

2.4.2. Ankle joint injuries in volleyball

Among 70 different types of sport, ankle (34.3%) was found to be the most commonly seen injury location, followed by knee and head (77). Even higher percentages of ankle injuries are reported in volleyball (38.9-45.6%), which is the 3rd most common sport (77,78).

In the literature, ankle sprains are reported to be the most common injury type among volleyball players (79,80). Lateral ankle ligament tears (11.1%) were found to be the most seen specific injury among National Collegiate Athletic Association (NCAA) female volleyball players between 2014 and 2019 (74). Beside the higher total injury rates of preseason period, specifically ankle injuries were mostly seen at competitions (18.7%) rather than practices (11.7%) (74).

In contrast to the game nature, ankle injuries are mostly seen in a contact mechanism (%59), which occurs by an acute ankle inversion when the players from opposing teams foot lands one another (75,81,82). In a recent study, the mechanism of lateral ankle sprains which happen in landing was investigated and it was reported that, contrary to popular belief, injuries in volleyball players occur when the ankle joint is in the neutral position rather than the PF position (83).

After the first ankle injury, functional instability of the ankle can continue in athletes. 20% of non-athletes develop instability after the first injury (84). However, it is presumable that this risk is greater in active populations, especially for professional athletes and they report higher residual symptoms at long term follow-ups (85,86). Among the ankle sprains seen in volleyball players, %46 were recurrent and 50% have sprained their ankle more than once (80).

2.5. Postural Adaptations Used in Volleyball

Adaptation is when a living thing undergoes changes related to itself in order to adapt to the external environment and its requirements (87). Postural adaptation is that, according to the perturbations originating from the outer or inner environments, the adaptation occurs to maintain a specific postural condition.

Every different sports branch develops a specific type of postural adaptation according to specific movements which occur in the play (88). With regular physical activity or training, adaptations can occur at both functional and structural levels (89). The adaptations can differ from sport to sport. Because different kind of sports require specific motor abilities, the movements and the posture adapts to meet the requirements of the tasks. Also to a certain sensory information will be needed for different kinds of postural adaptations.

For motor functions, the coordination of agonist and antagonist muscles regarding a specific duty, the ROM of hip and ankle joints, the muscle strengths and the reaction times of the specific muscle groups that are activated for that specific postural perturbation functionally improves. This results as more precise and accurate postural responses (90).

While with regular training, functional adaptations occur for as motor abilities to create specific postural compensation mechanisms, also neurological adaptations occur which can be called as central adaptations (91). When the athlete is getting used to specific postural adjustments, the need for somatosensory input will decrease by time. In contrast when the postural compensation task gets harder, the need for somatosensory inputs will increase (92,93).

About team sports, it is assumed that, because the movements on the fields are more active and fast, the adaptation of the postural control is more rapid (6). Also the adaptation seen in team sports differ from athlete to athlete according to the role they play on the field

(94). Because volleyball is a sport that every player has a different duty on the field, the adaptations that occur to ensure postural control will differ for every player.

Athletes who are trained on a stable surface like volleyball players are carrying out an ascending strategy as a postural adaptation (95). Against the force applied to the support surface, the support surface also applies the same force to the person in the opposite direction and positions the center of mass relative to the point where the force is applied (96). In other words, volleyball players perform the loading model from distal to proximal, which is initiated in the distal joints (especially the ankle), where necessary adjustments are made to provide postural balance.

The reactive motor control strategy is used by athletes like volleyball players is the reactive motor control strategy (95). This is a strategy used when the ground is stable and the perturbations comes from the environment and not from the surface. For volleyball players who are trained on a stable surface like the court, this strategy is used to maintain postural control.

3. MATERIALS AND METHODS

3.1. Subjects

This study was carried out between February 2022 and August 2022, with female individuals aged 18-25 years with stable ankle and no ankle injury in the last 1 year. The study consists of two groups: the volleyball group (VG, n=20), which includes volleyball players playing in university teams, and the control group (CG, n=20) includes healthy university students who meet the same criteria. The sample size of the study was calculated as 40 for the independent sample t-test, using the G-Power program (97).

A signed consent form (Appendix 1) was obtained from the volunteer participants who agreed to participate in the study. The study protocol was approved by the Yeditepe University Ethics Committee by 202202159 number. The eligibility criteria for this study are set out below:

Inclusion

• Female gender,

• Being between the ages of 18-25,

• Having a score of ≥24 on the Cumberland Ankle Instability Tool (CAIT),

• Volunteering for the study.

Exclusion

• Presence of neuromuscular system disease,

• Presence of vestibular or visual problems,

• Presence of acute or chronic pain,

• An ankle injury in the last year,

•For the control group, regular participation in sports activities or physical activity for more than 150 minutes, 5 days a week (1,6,98)

3.2. Study Protocol

First, demographic and clinical information of the participants who volunteered to participate in the study were filled with the "General Information Form for Volleyball Players and Students" (Appendix 2 and 3) by face-to-face interviews. The information obtained from the participants are:

• The person's name and surname, age, gender, height and weight information,

• Presence of chronic disease,

• Past orthopedic injuries,

• Presence of ankle injury in the last 1 year,

• Treatments received and surgeries performed,

• Medicines used,

• Presence of pain,

• For volleyball players: position played, number of years, frequency of training and matches,

• For the control group: physical activity and regular sports participation.

After filling out the general information form, the CAIT score was assessed for eligibility for the study of both extremities. After the selection of the eligible participants, first the static balance assessment of the individuals was measured with a computerized stabilometer (Prokin-252) while standing silently on the force platform. The data of the postural control variables were obtained through the computer connected to the device and recorded in the electronic environment. The tests were carried out in 3 repetitions for 30 seconds. The methods to be evaluated were performed on the extremity in which he preferred to hit the ball, that is, on the functionally dominant side (97,99,100) and the non-dominant side. For ankle function evaluations; the ankle range of motion (ROM) measurement of the person, then proprioception and vibration evaluations, which are somatosensory evaluations were performed, and finally the strength measurements of the muscles around the ankle joint were made by the help of JTECH Commander Powertrack Manual Dynamometer. The data were instantly recorded in the "Tabled Evaluation Form" (Appendix 4). All assessments took approximately 45-60 minutes with the rests and the participants were not followed up after the assessments.

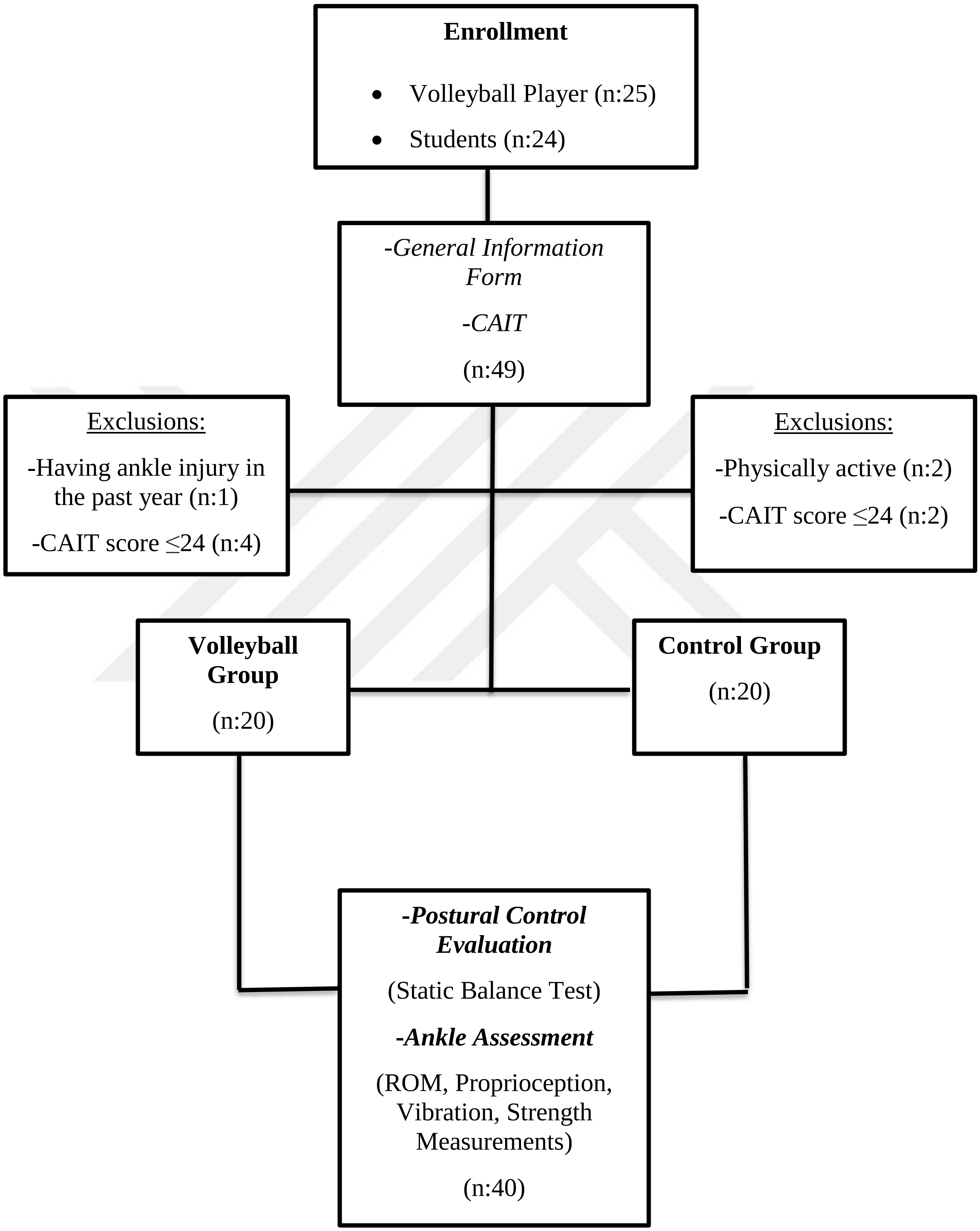

Figure 9: Flow chart of the study.

3.3. Assessments

3.3.1. Assessment of ankle stability

The CAIT was used to select suitable participants for the study. The scale consists of nine questions about both right and left ankle joint functions and whether there is pain in different activities and a total of 30 points can be scored. The tool has proven to be reliable and valid for evaluating ankle joint instability (101). CAIT distinguishes stable and unstable ankles from each other. Functional instability increases with lower scores from the scale. The cut-off point for a stable ankle is ≥24 points (102). Only people whose both ankles were considered stable according to the scale were included in this study (Appendix 5).

3.3.2. Assessment of postural control

Postural control was evaluated according to the results of the static stability test performed on the force platform of the computerized stabilometer (Prokin-252) which has proven reliability (Figure 10) (103). The static balance test was performed in a standing silent upright position for 30 seconds with eyes open (104,105). Before the test, explanation was made to the participant to stand still on the force platform. The test was carried out 3 times and the data were recorded instantly via the computer. Mean value data were used for data analysis of the test, which was performed as 3 repetitions. Verbal notification was not given to the person during the test unless necessary (98). A rest period of 60 seconds was given between repetitions.

Variables used in the study:

- Average postural sway velocity in the AP direction (mm/sec),
- Average postural sway velocity in the medial-lateral (ML) direction (mm/sec),
- Sway Area: Total displacement area of CoP (mm^2)
- Perimeter: Total displacement of CoP (mm) variables (99).

Figure 10: Assessment of static stability on the force platform via computerized stabilometer (Prokin-252).

3.3.3. Assessment of ankle functions

3.3.3.1. Ankle range of motion

The purpose of the ROM assessment is to detect ankle mobility. ROM assessment was made using a goniometer. DF and PF in the tibiotalar joint, and EVR and INVR in the subtalar joint were evaluated. All movements were asked to be done actively and passively on both dominant and non-dominant extremities. These evaluations were repeated 3 times and the average scores were recorded (106).

Dorsiflexion and Plantar Flexion ROM measurement:

The participant lies in the supine position and a thin pillow is placed under the knee. Since the gastrocnemius muscle folds two joints, it is aimed to relax in this way. The pivot point of the goniometer is placed on the lateral malleolus, with its fixed arm parallel to the lateral midline of the fibula, and its movable arm following the lateral midline of the 5th metatarsal bone.

Inversion and Eversion ROM Measurement:

The person lies in the prone position with the knee flexed at 90° and the ankle in a 90° neutral position. The pivot point of the goniometer is placed at the midpoint of the calcaneus. While the fixed arm is initially held parallel to the midline of the sole of the foot, it remains parallel to the ground after the movement begins. The movable arm follows the midline of the sole of the foot.

3.3.3.2. Sensory assessment of ankle

Joint Position Sense

Han et al. (2015) explained that ankle proprioception has an important role on balance control in athletes. Therefore, the evaluation of joint position sense (JPS) is used to measure the ankle position sense of the participants in our study (9).

Evaluation was performed with eyes closed. The person was supported in the supine position with a pillow under the legs and knees. The purpose of this is to bend the knee and relax the calf muscles. JPS is evaluated with the help of a goniometer. The pivot point is placed on the lateral malleolus, the proximal arm is parallel to the lateral midline of the fibula, and the distal arm is parallel to the 5th metatarsal. The goniometer did not come into contact with the skin during application. The foot is placed so that the starting position is 145° PF. 105°, 120°, 130° and 140° DF ROM are tested. Randomly positions the ankle passively to some degree of reference. Then the person loosens their foot to the starting position and is expected to return actively to the reference level. The angle reached by the participant with the goniometer is recorded. Three replicates are required, the mean value is referenced and recorded. The absolute value of the deviations from the reference angles was taken and used in the statistical analysis in degrees. Values moving away from the reference degree indicates a worsening of the position sense (107–109).

Vibration

Vibration disappearance threshold evaluation was made with the help of a tuning fork (128 Hz) (Figure 11). The eyes were closed throughout the application. Before the evaluation, a trial was conducted on the bone structure in order for the patient to feel and learn the tactile sense. The main reference points for the application are the big toe, fifth toe and medial malleolus (110). After the vibration sound was heard as soon as hitting the tuning fork on a hard surface, it was placed at the reference point. The person is asked to say when the feeling of vibration ends. A timer was used to count the time. Three applications were made for each point and the average value was recorded.

Figure 11: Vibration assessment on medial malleolus.

3.3.3.3. Muscle strength assessment

The maximum isometric strength of the ankle was evaluated with the manual dynamometer measurement, the validity and reliability of which has been proven (111,112). JTECH Commander Powertrack Manual Dynamometer was used for measurements (Figure 12).

The subtalar neutral position is taught to patients and each test must be started from this position. Extremities that do not participate in the application are fixed to the bed to eliminate accessory movements. DF, PF, INVR and EVR movements were evaluated (113). Before each measurement, the dynamometer was calibrated. The dynamometer is placed above the metatarsal heads during measurement. Participants were instructed to pull or push the device as hard as they could. The researcher tried to neutralize this force with both hands. Evaluation positions were performed in accordance with the procedures described by Hislop and Montgomery (114). After the test was performed for 3 seconds, 3 repetitions with 10 seconds intervals and recorded, the highest force value (Newton) was used for statistical analysis (113).

Figure 12: JTECH Commander Powertrack Manual Dynamometer.

4. STATISTICAL ANALYSIS

SPSS (Statistical Package for Social Sciences) version 24 was used to evaluate the data obtained in the study. Descriptive statistics were used to describe the general characteristics of individuals. In the presentation of quantitative variables, mean, standard deviation (SD), median, minimum and maximum values were taken. Shapiro Wilk test was used to test whether the variables were in accordance with the normal distribution in the groups. Independent sample t-test was used in the analysis of the difference between the two groups for normally distributed ankle functions and postural control variables. The Mann Whitney U test was used in the difference analysis of the variables that did not fit the normal distribution. Spearman Correlation Analysis was used for evaluating the relationship between ankle functions and postural control variables. r values were expressed as moderate correlation between 0.4-0.6, strong correlation between 0.6-0.8. In all statistical analyses, $p<0.05$ was accepted as significance level.

5. RESULTS

5.1. Descriptive Characteristics

Age, height, weight and BMI mean, SD, minimum and maximum values were obtained as demographic characteristics from 40 female participants (Table 1). The variables were normally distributed among groups according to the Shapiro Wilk test (p>0.05). There were significant differences between groups in terms of height and weight variables (p<0.05).

For the VG, sports specific characteristics were obtained. Table 1 presents the number of years the participants have played volleyball to date and the number of matches played per season. The years of volleyball played as volleyball history was normally distributed among the group (p>0.05) whereas the matches played per season was not normally distributed (p<0.05).

Table 1: Table of Demographic Characteristics of The Participants

	Group	Mean	SD	Minimum	Maximum	t	p
Age	**CG**	21.17	1.66	18	25	-0.056	0.955
	VG	21.20	1.90	18	24		
Height (m)	**CG**	1.62	0.04	1.54	1.70	-7.764	**0.000***
	VG	1.75	0.05	1.63	1.85		
Weight (kg)	**CG**	55.47	7.03	43	71	-3.897	**0.000***
	VG	63.53	6.01	49	77		
BMI	**CG**	17.11	2.10	14	22	-1.762	0.086
	VG	18.13	1.47	15	21		
Years Played	**VG**	10.22	2.04	7	14	-	-
Matches Per Season	**VG**	15.83**	-	10	35	-	-

VG: Volleyball Group, CG: Control Group, SD: Standard Deviation. *Independent Sample T-test: p<0.05, **Median.

Also, the training frequencies and the duration of these training sessions, which the players participate in during the season, are shown as categorical data (Table 2). 65% of the volleyball players which participated in the study undergone training 2-3 days a week. 50% of the volleyball players has a duration of 60 to 90 minutes and the other 50% has more than 60 to 90 minutes of training. The training frequency and duration was not normally distributed among the VG ($p<0.05$).

Table 2: Training Frequency and Duration of Volleyball Players

		Frequency	**Percentage (%)**
Training Frequency	**1 day/week**	0	0
	2-3 days/week	13	65
	4-5 days/week	4	20
	Everyday	3	15
	Total	20	100
Training Duration	**30-60 min**	0	0
	60-90 min	10	50
	90-120 min	8	40
	120 min+	2	10
	Total	20	100

5.2. Comparison of Ankle Functions Between the Groups

5.2.1. Comparison of active ankle joint rom between the volleyball and control groups

The active ankle joint ROM mean and SD data of both dominant and non-dominant extremity are presented in Table 3. DF, INVR and EVR active ROM has a statistically significant difference ($p<0,05$) between the VG and CG for dominant and non-dominant extremities in favor of VG, whereas PF did not differ between the groups for both extremities ($p>0,05$).

Table 3: Comparison of Active Ankle Joint ROM of the dominant and non-dominant extremity

Active ROM		VG Mean ± SD	CG Mean ± SD	t/Z	p
Dominant Extremity	**DF**	22.63 ± 4.40	16.50 ± 3.27	Z=-3.81	**0.000***
	PF	40.03 ± 7.86	38.05 ± 4.85	t=0.959	0.344
	INVR	32.31 ± 4.69	26.05 ± 3.73	Z=-3.89	**0.000***
	EVR	21.42 ± 2.70	17.98 ± 4.13	Z=-3.00	**0.002***
Non-dominant Extremity	**DF**	21.21 ± 4.27	16.17 ± 2.27	t=4.65	**0.000***
	PF	39.24 ± 6.19	36.08 ± 6.42	t=1.58	0.122
	INVR	31.31 ± 3.04	24.85 ± 3.00	t=6.75	**0.000***
	EVR	20.87 ± 2.62	16.60 ± 5.44	Z=-2.72	**0.006***

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, SD: Standard deviation, t: Independent Sample T-test, Z: Mann Whitney U Test, *Significant difference: $p<0.05$

5.2.2. Comparison of passive ankle joint rom between the volleyball and control groups

The passive ankle joint ROM mean and SD data of both dominant and non-dominant extremity were given in Table 4. As active and passive ROM; DF, INVR and EVR has a statistically significant difference ($p<0,05$) between the VG and CG for both extremities, whereas PF did not differ between the groups ($p>0,05$).

Table 4: Comparison of passive ankle joint ROM of the dominant and non-dominant extremity

	Passive ROM	VG Mean ± SD	CG Mean ± SD	t/Z	p
Dominant Extremity	**DF**	25.14 ± 3.99	19.44 ± 4.23	Z=-3.53	**0.000***
	PF	42.37 ± 5.11	40.45 ± 3.32	t=1.41	0.165
	INVR	30.39 ± 6.29	29.27 ± 5.90	Z=-2.33	**0.020***
	EVR	24.41 ± 3.99	21.25 ± 2.21	t=3.09	**0.004***
Non-dominant Extremity	**DF**	22.84 ± 4.30	20.48 ± 2.95	Z=-2.30	**0.021***
	PF	42.34 ± 4.23	41.20 ± 4.13	t=0.863	0.394
	INVR	34.75 ± 3.10	28.38 ± 3.08	Z=-4.50	**0.000***
	EVR	23.68 ± 1.90	21.79 ± 2.18	Z=-2.72	**0.006***

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, SD: Standard deviation, t: Independent Sample T-test, Z: Mann Whitney U Test, *Significant difference: $p<0.05$

5.2.3. Comparison of ankle joint position sense between the volleyball and control groups

Table 5 shows the mean and SD data of the absolute value of the deviations from the specified reference degrees (105°, 120°, 130° and 140°). The statistical analysis showed that, for both of the extremities, the JPS has a statistically significant difference at all of the reference degrees which is in favor of the VG ($p<0,05$).

Table 5: Comparison of ankle joint position sense of the dominant and non-dominant extremity

JPS		VG Mean ± SD	CG Mean ± SD	t/Z	p
Dominant Extremity	**105°**	0.90 ± 0.29	4.50 ± 0.57	Z=-4.38	**0.000***
	120°	0.85 ± 0.26	4.25 ± 0.55	Z=-4.27	**0.000***
	130°	1.65 ± 0.46	4.75 ± 0.52	Z=-3.95	**0.000***
	140°	1.15 ± 0.23	3.40 ± 0.47	t=4.23	**0.000***
Non-dominant Extremity	**105°**	1.80 ± 0.31	4.65 ± 0.43	t=5.35	**0.000***
	120°	1.20 ± 0.23	3.45 ± 0.36	Z=-4.31	**0.000***
	130°	1.85 ± 2.54	3.85 ± 0.33	t=4.75	**0.000***
	140°	1.50 ± 0.27	3.95 ± 0.41	t=4.92	**0.000***

JPS: Joint position sense, VG: Volleyball Group, CG: Control Group, SD: Standard deviation, t: Independent Sample T-test, Z: Mann Whitney U Test, *Significant difference: $p<0.05$

5.2.4. Comparison of vibration sense between the volleyball and control groups

For the vibration sense data which was assessed from the medial malleolus, the 1st and the 5th toe by both extremities are presented in Table 6. On both extremities the vibration sensed through the 1st and the 5th toe has a statistically significant difference ($p<0.05$) between the groups where the vibration sensed through the medial malleolus do not have a statistically significant difference ($p>0.05$) between groups for both extremities. CG has better result for vibration findings.

Table 6: Comparison of vibration sense for dominant and non-dominant extremity

		VG Mean ± SD	CG Mean ± SD	t/Z	p
Dominant Extremity	**Medial Malleolus**	11.92 ± 1.42	13.07 ± 3.00	t=-1.54	0.130
	1st Toe	12.53 ± 2.09	14.04 ± 2.50	t=-2.06	**0.046***
	5th Toe	13.06 ± 2.32	15.85 ± 3.06	t=-3.24	**0.002***
Non-Dominant Extremity	**Medial Malleolus**	12.25 ± 1.89	13.37 ± 2.42	t=-1.63	0.111
	1st Toe	12.97 ± 1.94	15.58 ± 3.30	t=-3.04	**0.004***
	5th Toe	12.69 ± 2.34	15.94 ± 1.90	t=-4.82	**0.000***

VG: Volleyball Group, CG: Control Group, SD: Standard deviation. *Significant difference: $p<0.05$

5.2.5. Comparison of ankle isometric muscle strength between the volleyball and control groups

The ankle joint isometric muscle strength was assessed by four directions which were, DF, PF, INVR and EVR movements for the dominant and non-dominant extremity (Table 7). The mean and SD results from the analysis showed that there was statistically significant difference between two groups when it comes to DF and PF muscle strength of both extremities ($p<0.05$). VG has higher muscle strength then CG for DF and PF movement. Other variables did not differ between these two groups ($p>0.05$).

Table 7: Comparison of ankle joint muscle strength of the dominant and non-dominant extremity

		VG Mean ± SD	CG Mean ± SD	t/Z	p
Dominant Extremity	**DF**	82.39 ± 13.31	72.40 ± 10.38	t=2.64	**0.012***
	PF	58.00 ± 12.58	44.86 ± 11.13	Z=-3.21	**0.001***
	INVR	33.80 ± 8.28	38.79 ± 11.66	t=-1.56	0.812
	EVR	26.65 ± 7.54	27.40 ± 11.70	t=-.24	0.127
Non-dominant Extremity	**DF**	75.36 ± 12.32	66.92 ± 9.02	t=2.47	**0.018***
	PF	56.34 ± 11.40	43.23 ± 8.93	Z=-3.42	**0.000***
	INVR	32.62 ± 4.20	33.65 ± 7.24	Z=-0.82	0.414
	EVR	25.36 ± 7.08	24.93 ± 10.70	t=0.15	0.881

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, SD: Standard deviation. *Significant difference: p<0.05

5.3. Comparison of Postural Control Variables Between the Groups

The mean and SD data are presented in Table 8. For the all of the postural control variables, there was statistically significant difference between these two groups (p<0.05). All of the variables were in favor of the VG.

Table 8: Comparison of postural control variables

	VG Mean ± SD	CG Mean ± SD	t/Z	p
AP Speed	6.10 ± 1.51	10.80 ± 3.39	Z=-4.49	**0.000***
ML Speed	4.80 ± 1.10	6.40 ± 2.68	t=-2.46	**0.018***
Ellipse Area	128.40 ± 90.05	335.95 ± 300.43	Z=-2.61	**0.008***
Perimeter	274.25 ± 48.82	420.85 ± 139.06	t=-4.44	**0.000***

VG: Volleyball Group, CG: Control Group, SD: Standard deviation, AP: Anterior-Posterior, ML: Medial-Lateral. *Significant difference: p<0.05

5.4. Correlation Between Ankle Functions and Postural Control of the Groups

5.4.1. Correlation between active ankle range of motion and postural control variables of the volleyball and control groups

The correlation between active ankle ROM and postural control variables are shown in Table 9. According to the results, for the VG there was statistically significant positive high correlation between active DF ROM of non-dominant extremity and AP speed variables (p<0,01), whereas for the dominant extremity there was statistically significant positive moderate correlation between active DF ROM and AP speed variables (p<0,05). For the VG, there was statistically significant positive high correlation between active EVR ROM of both of the extremities and ellipse area variable (p<0,01). Also for active EVR ROM of dominant extremity, statistically significant positive moderate correlation was found between perimeter variable as well (p<0,05).

For the CG, according to our results, there were no statistically significant correlation between any active ankle joint ROM and postural control variables (p>0,05).

Table 9: Correlation between active ankle joint ROM and postural control variables

			VG				CG			
			AP Speed	ML Speed	Ellipse Area	Perimeter	AP Speed	ML Speed	Ellipse Area	Perimeter
Dominant Extremity	DF	r	**0.448***	0.280	0.198	-0.008	0.011	0.071	0.006	0.073
		p	0.048	0.232	0.402	0.972	0.965	0.765	0.979	0.760
	PF	r	-0.314	-0.187	-0.384	0.074	0.225	0.314	0.349	0.265
		p	0.178	0.429	0.094	0.758	0.340	0.177	0.131	0.259
	INVR	r	0.016	-0.238	0.305	0.133	-0.192	-0.341	0.052	-0.251
		p	0.946	0.313	0.191	0.575	0.417	0.141	0.828	0.286
	EVR	r	0.187	0.434	**0.786****	**0.449***	0.050	0.172	0.153	0.076
		p	0.431	0.056	0.000	0.047	0.833	0.468	0.519	0.749
Non-dominant Extremity	DF	r	**0.569****	0.389	0.341	0.107	0.086	0.300	0.000	0.174
		p	0.009	0.090	0.141	0.653	0.717	0.198	1.000	0.464
	PF	r	-0.422	-0.222	-0.353	-0.027	0.182	0.243	0.138	0.164
		p	0.064	0.347	0.127	0.911	0.442	0.301	0.562	0.490
	INVR	r	-0.047	-0.177	0.176	-0.079	0.136	0.021	0.135	0.074
		p	0.845	0.456	0.457	0.740	0.568	0.930	0.570	0.758
	EVR	r	-0.035	0.275	**0.765****	0.346	0.267	0.285	0.002	0.239
		p	0.883	0.242	0.000	0.136	0.254	0.223	0.995	0.310

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, AP: Anterior-Posterior, ML: Medial-Lateral, *Spearman Correlation Coefficient (significant at 0.05 level), **Spearman Correlation Coefficient (significant at 0.01 level)

5.4.2. Correlation between passive ankle range of motion and postural control variables of the volleyball and control groups

Table 10 demonstrates the correlation coefficients between passive ankle ROM variables and postural control variables. For the VG, there was statistically significant positive moderate correlation between AP speed and passive DF of the dominant and EVR ROM of the non-dominant extremity ($p<0,05$). For passive INVR ROM of the non-dominant extremity, there was statistically significant positive moderate correlation with ellipse area ($p<0,05$).

For the CG, there was statistically significant negative moderate correlation between passive EVR ROM of the dominant extremity and AP speed variable ($p<0,05$). Also there was statistically significant positive high and moderate correlation between ML speed and passive PF of the dominant extremity ($p<0,01$) and INVR ROM of the non-dominant extremity ($p<0,05$). There was statistically significant positive moderate correlation between passive PF ROM of dominant extremity and perimeter variable ($p<0,05$).

Table 10: Correlation between passive ankle joint rom and postural control variables

			VG				CG			
			AP Speed	**ML Speed**	**Ellipse Area**	**Perimeter**	**AP Speed**	**ML Speed**	**Ellipse Area**	**Perimeter**
Dominant Extremity	**DF**	**r**	**0.450***	0.380	0.301	0.075	0.121	0.236	0.054	0.193
		p	0.046	0.099	0.198	0.754	0.611	0.317	0.822	0.416
	PF	**r**	-0.205	-0.342	-0.024	0.159	0.402	**0.546****	0.334	**0.477***
		p	0.386	0.140	0.919	0.502	0.079	0.010	0.150	0.033
	INVR	**r**	0.118	0.138	0.284	-0.062	0.072	0.437	0.110	0.300
		p	0.621	0.561	0.226	0.796	0.764	0.054	0.646	0.198
	EVR	**r**	0.105	0.003	0.308	0.291	**-0.453***	-0.388	-0.209	-0.401
		p	0.658	0.991	0.187	0.213	0.045	0.091	0.377	0.080
Non-dominant Extremity	**DF**	**r**	0.443	0.261	0.347	0.023	0.235	0.405	0.269	0.341
		p	0.051	0.266	0.134	0.925	0.318	0.077	0.251	0.141
	PF	**r**	-0.332	-0.233	-0.299	-0.029	0.120	0.357	0.339	0.212
		p	0.153	0.322	0.201	0.903	0.614	0.123	0.144	0.370
	INVR	**r**	-0.142	0.183	**0.486***	0.296	0.140	**0.492***	0.343	0.328
		p	0.549	0.439	0.030	0.205	0.557	0.028	0.138	0.158
	EVR	**r**	**0.450***	0.380	0.301	0.075	0.016	0.110	-0.059	0.117
		p	0.567	0.152	0.771	0.311	0.947	0.645	0.805	0.623

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, AP: Anterior-Posterior, ML: Medial-Lateral, *Spearman Correlation Coefficient (significant at 0.05 level), **Spearman Correlation Coefficient (significant at 0.01 level)

5.4.3. Correlation between ankle joint position sense and postural control variables of the volleyball and control groups

The correlations between ankle JPS and postural control variables are shown in Table 11. There was statistically significant positive moderate correlation between ellipse area and the absolute value of the deviation in degrees from 130° and 140° reference values only at the non-dominant extremity ($p<0,05$). No other ankle JPS variable was correlated with postural control variables ($p>0,05$).

For the CG, no statistically significant correlation was found between the JPS and postural control variables ($p>0,05$).

Table 11: Correlation between ankle JPS and postural control variables

			VG				CG			
			AP Speed	**ML Speed**	**Ellipse Area**	**Perimeter**	**AP Speed**	**ML Speed**	**Ellipse Area**	**Perimeter**
Dominant Extremity	**105°**	**r**	-0.030	-0.071	0.147	-0.286	-0.205	0.002	0.022	-0.074
		p	0.900	0.765	0.536	0.221	0.387	0.995	0.926	0.756
	120°	**r**	-0.250	0.071	0.403	0.167	0.003	0.117	0.096	0.052
		p	0.288	0.766	0.078	0.483	0.990	0.624	0.686	0.829
	130°	**r**	0.107	-0.191	0.424	0.316	-0.052	0.110	0.358	0.036
		p	0.655	0.419	0.062	0.175	0.829	0.645	0.121	0.882
	140°	**r**	-0.255	0.152	0.212	-0.043	0.233	0.415	0.218	0.308
		p	0.278	0.522	0.371	0.856	0.322	0.069	0.357	0.186
Non-dominant Extremity	**105°**	**r**	-0.025	0.246	0.125	-0.011	0.112	-0.186	0.180	-0.041
		p	0.916	0.297	0.599	0.963	0.640	0.433	0.449	0.863
	120°	**r**	0.380	0.364	0.371	0.059	0.103	-0.022	0.171	0.068
		p	0.098	0.115	0.107	0.804	0.667	0.925	0.471	0.776
	130°	**r**	0.299	0.321	**0.479***	0.314	-0.004	0.254	0.099	0.153
		p	0.201	0.167	0.033	0.178	0.988	0.280	0.677	0.520
	140°	**r**	0.144	-0.105	**0.494***	-0.078	0.291	0.298	-0.027	0.313
		p	0.545	0.659	0.027	0.743	0.213	0.203	0.910	0.179

VG: Volleyball Group, CG: Control Group, AP: Anterior-Posterior, ML: Medial-Lateral, *Spearman Correlation Coefficient (significant at 0.05 level)

5.4.4. Correlation between vibration sense and postural control variables of the volleyball and control groups

Table 12 demonstrates the correlations between the vibration sense and postural control variables for both of the groups separately. A statistically significant positive moderate and high correlation was found between ellipse area and the vibration sense at the 1st (p<0,05) and 5th (p<0,01) metatarsal heads just at the dominant extremity for the VG.

No statistically significant correlations have found between any vibration sense variables and postural control variables for the CG (p>0,05).

Table 12: Correlation between vibration sense and postural control variables

			VG				CG			
			AP Speed	**ML Speed**	**Ellipse Area**	**Peri-meter**	**AP Speed**	**ML Speed**	**Ellipse Area**	**Peri-meter**
Dominant Extremity	**Medial Malleolus**	r	-0.190	-0.031	-0.166	-0.248	0.130	0.193	-0.081	0.174
		p	0.423	0.897	0.483	0.293	0.586	0.414	0.734	0.463
	1st Toe	r	-0.087	0.106	**0.477***	-0.169	-0.011	0.378	-0.187	0.122
		p	0.715	0.656	0.033	0.477	0.962	0.101	0.431	0.610
	5th Toe	r	-0.136	0.185	**0.646****	0.157	0.214	0.444	-0.089	0.280
		p	0.568	0.436	0.002	0.508	0.364	0.050	0.710	0.231
Non-Dominant Extremity	**Medial Malleolus**	r	-0.346	0.024	-0.248	-0.243	0.143	0.016	-0.018	0.097
		p	0.135	0.920	0.293	0.302	0.547	0.948	0.940	0.683
	1st Toe	r	-0.256	-0.221	0.336	-0.214	-0.002	0.107	-0.096	0.012
		p	0.275	0.349	0.148	0.365	0.992	0.654	0.686	0.959
	5th Toe	r	-0.134	0.240	0.414	0.132	-0.022	0.362	-0.259	0.150
		p	0.573	0.309	0.070	0.578	0.926	0.117	0.270	0.527

VG: Volleyball Group, CG: Control Group, AP: Anterior-Posterior, ML: Medial-Lateral, *Spearman Correlation Coefficient (significant at 0.05 level), **Spearman Correlation Coefficient (significant at 0.01 level)

5.4.5. Correlation between ankle isometric muscle strength and postural control variables of the volleyball and control groups

According to our results which is shown at Table 13, there was statistically significant positive moderate correlation between ellipse area and the isometric strength at DF direction and statistically significant negative moderate correlation between ellipse area and isometric strength at EVR direction at the dominant extremity for the VG ($p<0,05$). Again for the VG, there was statistically significant positive moderate correlation between ML speed and isometric strength at INVR direction at non-dominant extremity ($p<0,05$).

For the CG, statistically significant positive moderate correlation was found only between AP speed and isometric strength at INVR direction at non-dominant extremity ($p<0,05$)

Table 13: Correlation between ankle isometric muscle strength and postural control variables

			VG				CG			
			AP Speed	**ML Speed**	**Ellipse Area**	**Perimeter**	**AP Speed**	**ML Speed**	**Ellipse Area**	**Perimeter**
Dominant Extremity	**DF**	**r**	-0.019	0.121	**0.471***	0.110	0.379	0.281	0.177	0.366
		p	0.937	0.611	0.036	0.644	0.100	0.230	0.455	0.113
	PF	**r**	0.139	-0.192	-0.082	0.056	-0.292	-0.216	-0.041	-0.233
		p	0.558	0.418	0.731	0.814	0.211	0.361	0.862	0.323
	INVR	**r**	0.027	0.263	0.226	0.139	-0.071	-0.072	-0.330	-0.034
		p	0.909	0.263	0.338	0.560	0.767	0.764	0.155	0.887
	EVR	**r**	-0.012	-0.031	**-0.452***	-0.221	-0.057	-0.356	0.085	-0.223
		p	0.960	0.895	0.045	0.348	0.811	0.123	0.721	0.345
Non-dominant Extremity	**DF**	**r**	-0.330	0.002	0.307	-0.100	0.210	0.101	0.097	0.145
		p	0.155	0.995	0.188	0.673	0.374	0.670	0.684	0.541
	PF	**r**	0.185	-0.120	-0.077	0.271	-0.029	-0.053	0.070	-0.071
		p	0.434	0.615	0.746	0.247	0.903	0.826	0.769	0.766
	INVR	**r**	0.009	**0.529***	0.214	0.065	**0.472***	0.136	0.198	0.342
		p	0.969	0.017	0.365	0.785	0.036	0.567	0.403	0.140
	EVR	**r**	0.038	0.201	-0.373	-0.216	0.115	-0.048	0.212	0.063
		p	0.875	0.395	0.105	0.361	0.628	0.840	0.369	0.792

DF: Dorsiflexion, PF: Plantar flexion, INVR: Inversion, EVR: Eversion, VG: Volleyball Group, CG: Control Group, AP: Anterior-Posterior, ML: Medial-Lateral, *Spearman Correlation Coefficient (significant at 0.05 level)

6. DISCUSSION

The aim of our study was to evaluate the differences between ankle functions and postural control variables of female university level volleyball players and their counterparts as the university students. We have only included participants who are considered as having stable ankles according to CAIT. The use of CAIT as inclusion criteria is regularly seen in the literature when it comes to differentiating stable and unstable ankle conditions. The cut off point for CAIT when describing stable and instable ankles differentiate between studies. When studying the validity and reliability of CAIT, Hiller et. al. (2006) has declared that the cut off score for having ankle instability was ≤27, and they have updated the score as ≤24 in 2011 (101,102). Also the International Ankle Consortium has accepted the cut-off score as ≤24 in 2013 (115). The reason why we only included participants who have stable ankles is that, to understand if sports specific training can differ some ankle functions and postural control abilities from sedentary counterparts.

Demographic Information

We included 40 female participants in our study. Some studies in the literature have proven that, female population has more ankle sprains and also the severities when compared to male counterparts are higher (116,117). That is the reason why our study only contains female participants. In addition, the physical fitness parameters of male and female athletes are very different from each other. That is why we continued our work with a more homogeneous community.

For the VG we included volleyball players from the university team of Yeditepe University. The age, height, weight and BMI was normally distributed among the group. Averagely, the volleyball experience of the group was 10 years. Among the athletes, most of them (65%) were training 2 to 3 days a week. Also about the duration of these training, most of the athletes were training for 60 to 90 minutes (50%) or 90 to 120 minutes (40%).

For the CG we have included the students who were studying at Yeditepe University. The age, height, weight and BMI was normally distributed among the group. We have included participants to this group which did not have extra physical activity participation. Kuczyński et al (2009) included a control group that were physically active when searching the differences between second league male volleyball players and counterparts (5). In contrast, as our study, most of the studies that compared the differences of postural control or balance variables between a control group and an athlete group, have included sedentary participants to their study (1,6,98).

Range of Motion

In the study, the ROM was assessed as an indicator of ankle joint mobility. According to our results, all active and passive movements except PF of the VG were found to have a significant difference in dominant and non-dominant extremity when compared to CG. The mean scores were higher for the VG in all 4 directions for both extremities.

There are small numbers of studies which mentions the differences between ankle ROM values among athletes and controls. Because athletes need wide joint ROM to perform sport-specific movements, with regular training the ROM of the ankle joint could be increased. In a systematic review conducted by De Noronha et. al. (2006), decreased DF ROM resulted to stiffness of the ankle joint and caused problems at jumping and landing mechanics which are some of sport specific movements of volleyball play (64). So it can be assumed that with regular volleyball training, ankle ROM could be increased according to the needs of volleyball play.

The reason why only PF movement has no statistically significant difference between the groups may vary according to the requirements of the sport. Hamilton et. al. (2016) reported that the use of specific shoes while regularly coming on tiptoes is a factor which leads to increased PF ROM among ballet dancers (118). The volleyball players are using the ankle in DF position more than PF during training (119). Frasson et. al. (2009) observed that the active PF ankle joint ROM for dominant and non-dominant extremity of volleyball players (60°) were lower than both ballet dancers (83°), non-athlete physically active subjects (68°) (120). The PF ROM of volleyball players were close to non-athlete physically active subjects and also to normal population (48°) which indicates that volleyball players have similar PF ROM with these populations (118). According to these findings, the result in our study is in accordance with these results stated above.

The reason why the PF ROM of the VG was not superior to CG could be that; there is no need of wide degrees of PF ROM when it comes to volleyball play. In line with the requirements of the game, volleyball players use their plantar flexor muscles intensely eccentrically, that is, while the muscle lengthens for example at like shearing movements and running that require a sudden change of direction (120). And this contraction does not need a wide degree of PF ROM because the length of the muscle does not shorten while the contraction. They perform the needed load transfers of the body while the ankle is in DF position (121). Apart from these movements, while the volleyball players are waiting for the opposing team to attack in the stationary periods in the game, the players, except for the players who need to block, are constantly waiting in the DF position depending on the flexion of the hips and knees. This is because they must stand ready as it will make it easier for them to defend the ball attacked on their own court during the opposite team's attack. Controversially ballet dancers stay on their tip toes most of the time during their performance while the plantar flexor muscles are contracted concentrically (118).

As for the movement which the PF muscles are contracted concentrically are the jumping movements. Frasson et. al (2007), who investigated the relationship between torque and angle in the ankle joint in volleyball players, observed that the increase in maximal torque was associated with decreased PF movement (121). It should not be forgotten that the jumping and landing sequence is a whole (122). When the jumping-landing biomechanics are searched, it is known that the landings should be performed in a way that first the toes than the heels should touch the surface with increased knee and hip flexion and an optimal DF to decrease the risk of injuries on lower extremity (123,124). DF movement of the ankle is important because the movement during landing is like a squat, so an optimal DF is required to perform a correct squat and to stabilize the knees behind the toes (125). Sinsurin et. al. (2013) revealed in a study that volleyball and basketball players use 20° of DF at foot contact while landing not just from forward jumping but from different directions as well (126).

In the literature there are no studies reporting the average ROM values of volleyball players. It should be not forgotten that our results were in favor of the VG for PF ROM data without significant difference. Taking into account all these movements and positions that volleyball players are used to do with regular training, the result of our study that the groups do not have significant differences when it comes to PF ROM could be expected and also have been reported earlier in the literature (120).

Joint Position Sense

For the JPS assessment of the ankle, we have used the assessment that Rein et. al. (2011) have stated in their study (107). In the analysis, it was seen that the all the absolute deviation values from the reference degrees for the dominant and non-dominant extremity was significantly different between groups. The values that has significant differences among the groups were in favor of the VG. Other variables of JPS did not differ between groups.

Ankle proprioception plays an important role not just for injury prevention but also for performance ability. The years of sports participation and the proprioception ability of the athlete positively affects the sports performance (127). There are studies in the literature that are proving that athletes have better joint position sense then controls (127,128). Specifically, for volleyball players, a study investigating the differences between healthy controls and athletes in terms of ankle JPS measurements has not been conducted yet. Therefore, there is no study that can be a reference to the results of our study for ankle JPS variable.

The method used to assess JPS was a test performed with DF movement on the ankle. Higher end points of the joint can lead to better position sense results especially for 105° because while the assessment, DF movement reaches the end points of the existing ROM of the ankle. Also it was stated that volleyball play includes specific movements which DF is required regularly. Similar to our results, in a study, it was shown that the JPS improved for a specific joint in the positions frequently used by sport-specific volleyball training compared to healthy controls (97). So it might be assumed that, frequent training of specific movements for volleyball players could lead to improved ankle JPS of the joint when compared to healthy controls.

Vibration

There are studies which have assessed vibration sensitivity on populations with pathologies like hamstring strains or CAI but, there is no study in the literature that has compared the vibration sensitivity between healthy athletes and sedentary controls. So our study is the first to assess this outcome for healthy athletes. We found that the CG has better result for vibration sense at the first and fifth toe for both extremities, whereas the difference between the vibration sense was not significant at medial malleolus for both extremities between the groups. The literature has proven that the vibration sensitivity of the injured body parts is lower than of healthy controls or healthy limb and can be improved with different treatment methods (129,130).

According to an early study which used the same measurement technique as in our study, investigating the normative data for vibration sensitivity for both genders in the medial and lateral malleolus, both of our groups (VG: 11.92 ± 1.42, CG: 13.07 ± 3.00) fell behind the aforementioned normative data (19.6 ± 4.4) at medial malleolus which were given for healthy subjects who were at the ages between 20-29 (131). There are some factors that affects the sensitivity thresholds like age and height. Bartlett et al. (1998) have reported that increased height was correlated with increased vibration threshold (132). They have proven that, vibration threshold values at the foot of participants at the same age increased at a certain rate with every 10 cm increase in height. Because the mean height values of our VG (1.75 ± 0.056 cm) is higher than the CG (1.62 ± 0.049 cm), also this might be a contributing factor to support our results.

In additionally, it was assumed by Schlee et. al. (2007) that athletes participating in a sport performed with shoes (volleyball) have lower vibration sensitivity than athletes who do their sports with bare feet (gymnasts) (133). They have declared that with trainings done with shoe can be a factor affecting vibration sense. So the reason why volleyball players has lower vibration sensitivity might be because of shoes. But, to perform court sports without shoes could lead to other kinds of pathologies. Also healthy controls are wearing shoes at daytime. The shoe selection might be a criterion about vibration sensitivity.

We know that vibration sensitivity can be developed with different exercise or treatment techniques (130). Considering the previously proven relationships between somatosensory function and sports performance (10), the exercises included in the training programs of the VG included in our study and other studies should be questioned. Volleyball specific training may not be sufficiently focused to improve vibration sensitivity. However, more detailed studies which examines more factors are needed to reach a definite conclusion on this subject especially with healthy subjects and athletes.

There is a study proving that there is relationship between vibration sensitivity and muscle strength for patients who have knee osteoarthritis (134). In the study lower muscle strengths are associated with decreased vibration sensitivity. In our study there was no statistically significant differences between groups in terms of evertor and invertor isometric muscle strengths between the two groups and this can also be associated with the low vibration sensitivity in the VG that we included. More studies are needed on this subject in order to reach precise and detailed conclusions.

Isometric Muscle Strength

The muscle strength assessment was made to understand the effects of regular volleyball training on ankle joint muscle strength. Our study has revealed that there were significant differences between groups for only DF and PF movements for both extremities and they were in favor of the VG. Recent studies have shown that; for volleyball, power and strength variables are some of the most dominant parameters of the sport and it is believed to have strong correlation with volleyball specific game performance (135,136). It was stated that, volleyball is based on the development of muscle strength in order to adapt to intermittently strong and rapidly developing and changing movements, rather than a fixed game that requires extreme endurance (137). Spiking and blocking are two main volleyball-specific movements. Spiking, blocking and landing requires adequate harmony between concentric and eccentric muscle activity (8). A study has revealed that soccer players who has superior result of concentric PF strength could jump higher than others (138). Because dorsiflexor and plantar flexor muscle strength is a key to better performance, regular strength training to improve this condition is common when it comes to volleyball training. So our result is clearly demonstrating that, with regular volleyball training, the strength of ankle dorsiflexor and plantar flexor muscles increases according to the needs of the sport.

In our study, the invertor and evertor muscle strength of the groups did not differ statistically. The literature has proven that the imbalance between invertor and evertor muscle strength as a risk for ankle sprain (8), but there are no studies in the literature that has assessed the differences of evertor and invertor muscle strength between athletes and controls.

Postural Control

As an indicator of postural control, the static stability of the participants has been assessed by a computerized stabilometer. For all the variables, the postural control of VG was increased statistically significant results when compared to CG. There are studies which have assessed postural stability which included different groups that has different competitive levels. As in accordance with our study, studies compared both male and female elite volleyball players with controls for the outcome of static stability and concluded that VG has better results (1,6). In contrast, Şahin et. al. (2015) have stated that for sub-elite young female volleyball players, there was no statistically significant differences between the volleyball players and the sedentary controls at overall stability (OSI), anterior-posterior instability (API), and medial-lateral instability (MLI) indexes as variables of postural stability (97). Our study has included female athletes from a university team which could be considered as sub-elite level and still we have found that there were significant differences between groups.

The variables that have been used in our study are considered as objective variables to assess postural control. The displacements seen of the CoP are often used to investigate postural control variables but, there is no consensus on which of the many different variables best reflects postural control (139). We have used 4 variables to assess postural control on the static stability test: average postural sway velocity of the CoP in the AP and ML direction, total displacement and displacement area of CoP which were referred as perimeter and sway area (99). Sway velocity represents the degree of oscillation of CoP per second, so actually higher average oscillation degrees per second represents worsening postural stability (140,141). The average sway velocity for both AP and ML directions, the VG has lower values which is revealing a better postural stability. When considering the superiority of sway area and perimeter, because they refer to the total displacement and displacement area of CoP, lower results indicates better postural control (141). According to our study, the VG has lower scores from sway area and perimeter.

There are studies indicating that, volleyball players have better postural control than healthy controls by means of static stability. As the same result as our study, Borzucka et. al. (2020) concluded that the female and male athletes have developed strong postural control and strong defense mechanisms due to the balance and adaptability parameters they need during the game (1,6). Kuczyński et. al. (2009) which resulted as the same, stated that the strategies used by the athletes, different from the controls, may have superior postural stability because they can make slight muscle adjustments thanks to different mechanisms in order to suddenly move their bodies vertically more stably during the rapidly changing game (5).

Correlation Between Postural Control and Ankle Joint Function Variables

Because postural control is found to be a risk factor for ankle injuries, searching the factors that are in relation with postural control is of great important to prevent possible injuries in the future, especially for athletes. Our study is the first to assess the correlations between different ankle functions and postural control variables of volleyball players.

ROM and Postural Control

Although there are different results on this subject in the literature, the results in our study shows that there is positive correlation between active DF ROM of both of the extremities, passive DF ROM of dominant extremity and AP speed variable for the VG. Also again for the VG, active EVR ROM of both of the extremities is found to be positively correlated with ellipse area.

In the literature, most of the studies which have searched the relation between ROM and postural control variables included participants from geriatric populations and very few of them have included younger populations (142–145). The studies which were in accordance with our study revealed that, in unipedal quiet stance, increased passive DF ROM was associated with sway area and AP sway variables (143,145). This shows that the increase in ankle DF ROM can be a factor which is negatively affecting postural control ability. Also the passive PF ROM of the healthy students in our study had significant correlations with ML speed and perimeter variables. Kim et al. (2018), which also included healthy young adults (age: 19.85 ± 1.25) in their recent study have resulted that, instead of DF ROM, active and passive PF ROM was positively correlated with an average data of sway velocity and sway length which revealed that increased PF ROM was effecting postural control negatively (46). Controversially, according to the study of Sung et al. (2018), in healthy university students, lower active PF ROM was associated with poorer postural control ability (146).

Also in the study of Kim et al. (2018), it was stated that the limitation of their study was to not assess INVR and EVR ROM, which our study covers. There are very limited number of studies investigating the relationship between INVR and EVR ROM and postural control variables yet it was reported that these variables take significant roles when it comes to postural control (147). Again in the study of Bok et al. (2013), the researchers have reported that there was significant correlation between EVR ROM and ML sway and OSI for elderly subjects (143). In our study, there was positive correlation between active EVR ROM and ellipse area variables. Increasing OSI value reflects the angular movements of the participant's CoP, which means that increasing values in the index have more active test processes (poor postural stability) (148,149). Therefore, it can be said that the results shown supports the result of our study.

According to the result stated above, there are studies with contradictory results in the literature about the relationship between ankle ROM and postural control variables. While some say that increased ROM values negatively affect postural control, others point out that limited joint movements cause this (142,150). From these results it can be concluded that, optimal ankle movements may be the key point in achieving better postural control (46). Because the increase in ankle ROM (active or passive) is occurring by the looseness or stiffness of the structures surrounding or forming the joint, excessive looseness of these structures causes stability problems in the ankle (150). Since ankle stability is highly important for the postural control mechanism, it can be concluded that ankle joint ROM, which are higher than the optimal values, negatively affect postural stability and control.

JPS and Postural Control

There are studies which are supporting the idea that the ankle JPS and postural control parameters, are directly linked to the risk of ankle injury (9,64,151). Both ankle JPS and postural control parameters was found to be negatively correlated with ankle injuries. Despite this risk, mechanoreceptors are also damaged after ankle injuries which is related to the damage of soft tissues surrounding the joint (152). It therefore detrimentally alters the quality of proprioceptive information necessary for balance control. The sense of JPS, which changes negatively after the injuries, leads to deterioration in postural control ability in the long term

(153). These results are supported by the results of the studies which have assessed the variables through athletes as well (154,155).

According to our study, there was positive significant correlation between ellipse area and the ankle JPS at 130° and 140° of only the non-dominant extremity for the VG and no significant relationship was found between other variables. Our results show that the error in the JPS assessment and the area created by the displacement of CoP in the power platform increase in relation. There are studies which included different kinds of athlete populations and has results which are in accordance with our study. According to the study of Fu et al. (2005), the data achieved from the stabiliometry (AP sway angle) at quiet stance and ankle repositioning test were positively correlated for basketball players (13). We should not forget that while proprioceptive strategies used to provide postural control differ even among athletes doing the same sport, it becomes very difficult to make specific comments about the relationship between these variables according to studies which have included different populations (156).

For the CG of our study, we could not find any significant correlations between these variables. We know that postural control is affected by multiple factors. Although it is difficult to comment on the results we found for the control group, the difference in JPS between the two groups as well as isometric muscle strength assessments may be the factors that led us to this conclusion.

Vibration and Postural Control

According to the studies that have been conducted about vibration sensitivity and postural control, lower vibration sensitivity is in relation with impaired postural control or balance. Studies conducted in patients and elderly groups have shown a negative relationship between vibration sensitivity and postural control variables (157,158). Controversially, the vibration sensitivity in the forefoot was in relation with the displacement area of CoP in the power platform according to our study.

We have found that there is positive correlation between ellipse area and the vibration sense which was assessed at the 1st and 5th metatarsal heads of the dominant extremity just for the VG. Because we found positive significant correlation between these variables, our results are indicating that increased vibration sensitivity is correlated with poor postural control ability which does not support the findings of other studies in the literature. The studies which have searched the relation between vibration and postural control variables are taken from different kind of populations and some have used different kind of methods to assesses vibration sensitivity. According to the studies in the literature, there are known factors that are effecting sensitivity like anthropometric parameters or age and these factors are special to the person (132,159,160). Also it should be taken into account that our VG had poorer vibration sensitivity than our CG. Since the number of studies on this subject is very few and no other studies have search the vibration sensitivity at volleyball players or athletes, it is very difficult to reach definite conclusions on the subject.

Isometric Muscle Strength and Postural Control

It is known that the strength and coordination of the muscles located at the lower extremity is essential to provide optimal postural stability and control (161). In our study for the VG, ellipse area had significant positive correlation with dorsiflexor and significant negative correlation with evertor isometric muscle strength both at the dominant extremity. Also the invertor isometric muscle strength was positively correlated with AP and ML speed for the VG and CG in the non-dominant extremity. This means that while the sway velocity is in relation with invertor muscles, the dorsiflexor and evertor muscles are in relation with the displacement area of the CoP.

When compared to our CG, unlike our study, for healthy young adults and elderly it was reported that both isometric muscle strength of dorsiflexor and plantar flexors was effecting postural control positively (19,46). These studies include populations with different characteristics. Athletes are a unique population with their physical adaptations that occur according to the needs of a particular sport. In the recent study of Trajković et al. (2021) which searched the relation between postural stability and isometric muscle strength by the maximal voluntary contraction torque in 655 highly trained athletes from 9 different sports have found that, dorsiflexor and plantar flexor muscle strength was positively correlated with total CoP, AP and ML sway velocity on single-leg stance (162). Despite the fact that they have used single leg stance test to assess postural stability, they have concluded in a result that is in accordance with our study as dorsiflexor and plantarflexor muscle strength and postural stability variables are positively correlated.

As mentioned before both in the literature and in the results of our study, it is known that there is a significant difference in favor of the athletes in the muscle strength between the athletes and non-athlete populations (163). In our study, there was significant difference, especially in dorsiflexor and plantar flexor muscle strength between groups in favor of the VG. The reason for the difference between the relationship of the variables in athletes and in other groups, especially for DF and PF movement, may be based on the differences in muscle strength parameters of the populations. While higher muscle strength affects postural control negatively (like athletes), in populations who are having average, near-average or lower than average muscle strength (like healthy subjects or elderly), muscle strength values approaching the mean could be affecting postural control positively. In other words, it can be said that especially optimal dorsiflexor and plantar flexor muscle strength is a factor affecting postural control positively, considering that in standing silent stance oscillations mostly occur in the AP direction and the AP sway is under the control of the ankle joint highly by DF and PF movements (164).

There are very few studies that have examined the relationship between muscle strength and postural control evaluated for INVR and EVR movements in athletes. In a study that have searched the relations of these variables in 19 recreational athletes who had a history of ankle sprain has concluded that there was negative moderate correlation between isometric strength of evertor muscles and AP displacement of CoP (165). This results are indicating that better postural control is associated with increased evertor isometric muscle strength. Evertor muscles, which support the connective tissues around the joint, contribute significantly to joint stability (72). It is previously mentioned that ankle joint stability is important for postural control. For this reason, increase in the strength of the evertor muscles positively affects the postural control ability. Because we have included participants who are having stable ankles according to the CAIT, it can be assumed that volleyball players developed a postural control mechanism based on the strength of the ankle evertor muscles.

There is proof that athletes develop specific mechanisms to cope with oscillations and different kinds of perturbations. In addition, these mechanisms differ even sport to sport.

Therefore, it is very difficult to relate the correlation data obtained from volleyball players with the results of healthy controls or injured ones, the elderly, and even groups that play different types of sports.

Importance and Limitations of the Study

The strong part of this study is that, even though the postural control variables of static stability result have been assessed by some studies, till now according to our search no study has compared all of the different ankle functions between volleyball players and healthy controls. To understand the effects of regular training in a specific sport and see which of the variables are changed when compared to controls are of great importance to understand which sport affects which ankle parameters. Because ankle joint is among the most important joints for volleyball sport and is the most injured joint, it is of great importance to describe the developments in ankle functions and to reveal the relationships between these variables. The assessments which were used in this study for ankle functions were all practical methods and could be integrated in clinical practice easily. When it comes to the postural control assessment, the static stability test which was measured via computerized stabilometer was an objective method and a gold standard for this kind of assessment.

When we look at the limitation of the study, we included colligate volleyball players and healthy controls who were having stable ankles. In another point of view, a group which included volleyball players who were having instability at ankle joint could be added to the study but this was not the main aim of this study.

Due to the postural stability needs during the game, this parameter improves compared to the controls in the athletes who train frequently. The ankle joint assessment methods used in this study is promising because it can easily be implemented to clinical environment. Even though there are no certainty that all of the parameters assessed for ankle joint functions are superior at volleyball players than controls, these results are encouraging that, specific sport training can improve ankle joint functions that are considered as risk factors for ankle injuries like insufficient or excessive ROM, impaired JPS and imbalanced muscle strength. Our results have revealed that; DF, INVR and EVR ROM, ankle JPS, isometric muscle strength of dorsiflexor and plantar flexor muscles and postural control improves with regular volleyball training whereas vibration sensitivity does not. Also understanding the relationships between ankle functions and postural control is of great importance to train successful and healthy athletes. According to our results; while increased active and passive ROM and isometric strength of dorsiflexor and invertor muscles and vibration sensitivity was correlated with poorer postural control, improved JPS and isometric evertor muscle strength was correlated with better postural control. So it could be assumed that, including proprioceptive and muscle strengthening protocols in training programs of volleyball players may reduce the risk of ankle injury as it will positively affect postural control. To conclude, sport-specific training is a factor for improvement of specific ankle joint functions and postural control abilities according to the needs of play and should be assessed regularly.

7. CONCLUSION

- The static stability of volleyball players was found significantly better than the healthy controls.
- For active and passive ROM assessments of volleyball players, there was significant differences between groups in terms of DF, INVR and EVR ROM at both of the extremities.
- The volleyball players had significant and better results from ankle JPS assessment, isometric dorsiflexor and plantar flexor muscle strength.
- The control group has significantly more felt the vibration sense on 1^{st} and 5^{th} metatarsal heads than the volleyball group.
- While the ankle DF ROM is associated with sway velocity, the EVR ROM is associated with sway area of the CoP.
- There is a positive relationship between joint position sense error and CoP area measurement, as the error increases, so does the sway area.
- The vibration sense in the forefoot is correlated with the sway area.
- While the sway velocity is related to the invertor muscle groups, the dorsiflexor and evertor muscle groups are related to the sway area.

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9. APPENDICES

9.1. Appendix 1 Informed Voluntary Consent Form

BİLGİLENDİRİLMİŞ ONAM FORMU

ÇALIŞMANIN ADI: **Üniversite Düzeyindeki Voleybolcuların Ayak Bileği Fonksiyonları ve Postural Kontrol Değişkenleri Yönünden İncelenmesi**

Aşağıda bilgileri verilen araştırma çalışmasına katılmanız istenmektedir. Araştırmaya katılıp katılmama kararı tamamen size aittir. Katılmak isteyip istemediğinize karar vermeden önce, araştırmanın neden yapıldığını, bilgilerinizin nasıl kullanılacağını, çalışmanın neler içerdiğini, potansiyel yararları ve risklerini anlamanız önemlidir. Lütfen aşağıdaki bilgileri dikkatlice okumak için zaman ayırın. Çalışmaya katılmaya karar verirseniz, Çalışmaya Katılım Onayı kısmını imzalayın. Çalışmadan istediğiniz zaman ayrılmakta özgürsünüz. Çalışmaya katılımınız için size herhangi bir ödeme yapılmayacak veya sizden herhangi bir maddi katkı talep edilmeyecektir. Araştırmada kullanılacak tüm materyaller ve olası tüm masraflar araştırmacı tarafından karşılanacaktır.

ÇALIŞMANIN KONUSU VE AMACI:
Çalışmamızın amacı, üniversite düzeyindeki voleybolcuların ayak bileği fonksiyon ve postural kontrol değişkenleri yönünden incelemektir.

ÇALIŞMA PROSEDÜRLERİ:
Çalışmaya 18-25 yaş arası voleybolcular ve sağlıklı öğrenciler dahil edilecektir. Bu çalışmanın örneklem büyüklüğü 40 kişi olacaktır. Çalışmaya dahil edilmek için Cumberland Ayak Bileği İnstabilite Aracı doldurulacaktır. Anket sonucuna göre çalışmaya uygun olan kişiler dahil edilecektir. Çalışmaya katılacak olan kişilerin farklı ayak bileği fonksiyonları değerlendirilecektir. Ayak bileğinin hareketliliği, hareket açıklığı ölçümü bir gonyometre yardımı ile değerlendirilecektir. Ayak bileği ekleminin farklı derecelerdeki pozisyon hissi bir gonyometre yardımı ile ve vibrasyon hissi ise bir diyapazon ile değerlendirilecektir. Kas kuvveti, ayak bileği çevresi kasların hareketleri esnasında manuel dinamometre yardımı ile ölçülecektir. Sessiz duruş sırasında statik denge PK Prokin 252 sistemi ile değerlendirilecektir. Ayrıca testler öncesinde demografik bilgi formu doldurulacaktır. Katılımcılara her test arasında dinlenme süreleri verilecektir. Değerlendirme süresi her katılımcı için yaklaşık 45-60 dakikadır. Katılımcılar değerlendirme sonrasında takibe alınmayacaktır.

Danışmanlığı Dr. Çiğdem YAZICI MUTLU tarafından yapılan bu araştırma, Fizyoterapist Ayşem Ecem Özdemir tarafından yürütülecek ve Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Fizyoterapi ve Rehabilitasyon Anabilim Dalı'nda gerçekleştirilecektir

ÇALIŞMAYA KATILIMIN FAYDALARI NELERDİR?
Araştırmadan elde edilecek sonuçlara göre; voleybolcuların ayak bileği fonksiyonları ve postüral kontrol yetenekleri hakkında daha fazla bilgi sahibi olunmasının yanında, sporcu sağlığı alanında çalışan fizyoterapistlere, spora spesifik geliştirilen antrenman ve rehabilitasyon programları oluşturmak adına fayda sağlayacaktır.

KİŞİSEL BİLGİLERİM NASIL KULLANILACAK?
Araştırmacı, araştırma ve istatistiksel analiz yapmak için kişisel bilgilerinizi kullanacak, ancak kimliğiniz gizli tutulacaktır. Etik kurullar veya resmi makamlar, sizinle ilgili bilgileri ancak gerektiğinde inceleyebilecektir. Çalışmanın sonunda kendi sonuçlarınız hakkında bilgi isteme hakkınız vardır. Çalışma sonuçları, çalışmanın sonunda tıbbi literatürde yayınlanacak, ancak kimliğiniz ifşa edilmeyecektir.

SORU VE SORUNLARINIZ İÇİN İLETİŞİM:
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ÇALIŞMAYA KATILIM ONAYI

Yukarıdaki bilgileri ilgili araştırmacı ile detaylı olarak görüştüm ve tüm sorularımı yanıtladı. Bu bilgilendirilmiş onam belgesini okudum ve anladım. Kendi özgür irademle bu araştırmaya katılmayı ve bu onam formunu imzalamayı kabul ediyorum. Çalışmanın sonuçlarının tıbbi literatürde kullanılmasını kabul ediyorum. Talebim ile araştırmadan istediğim zaman çekilebileceğimi biliyorum. Bu onay, geçerli yasa ve yönetmelikleri geçersiz kılmaz. Araştırmacı, saklamam için bu belgenin bir kopyasını bana verdi.

Gönüllünün Adı ve Soyadı:	
İletişim Bilgisi:	
Adres:	
Tarih/İmza:	

Tanık Adı ve Soyadı:	
İletişim Bilgisi:	
Tarih/İmza:	

Yürütücü Araştırmacı Adı ve Soyadı:	
İletişim Bilgisi:	
Adres:	
Tarih/İmza:	

Sorumlu Araştırmacı Adı ve Soyadı:	
İletişim Bilgisi:	
Tarih/İmza:	

Katılımcıya bahsi geçen çalışma ve yapılacaklar ile ilgili gerekli bilgileri verdim. Katılımcıların bilgileri anladığına, sormak istedikleri soruları sorduğuna ve süreci özgür iradesi ile kabul ettiğine inanıyorum.

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İmza:

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9.2. Appendix 2 General Information Form for Volleyball Players

<u>Voleybolcular İçin Genel Bilgi Formu</u>

<u>Genel bilgiler:</u>

• Adı ve soyadı:......

• Doğum tarihi/Yaş:......

• Cinsiyet:......

• Boy uzunluğu:.......

• Vücut ağırlığı:......

<u>Genel sağlık durumu:</u>

• Kronik bir hastalık varlığı: Evet (..........................) / Hayır

• Geçirilen ameliyatlar: Evet (..........................) / Hayır

• Geçirilen Yaralanmalar: Evet (..........................) / Hayır

• Kullanılan ilaçlar: Evet (..........................) / Hayır

• Son 1 yılda ayak bileği yaralanması geçirdiniz mi? Evet / Hayır

• Alınan Tedaviler: Evet (..........................) / Hayır

• Kronik veya akut ağrı varlığı: Evet (..........................) / Hayır

<u>Spora özel bilgiler:</u>

• Oynanan pozisyon:......

• Oynanan yıl sayısı:......

• Antrenman sıklığı: Haftada 1 / Haftada 2-3 / Haftada 4-5 / Her gün

• Antrenman süresi: 30-60 dk / 60-90 dk / 90-120 dk / 120+ dk

• Sezon başına ortalama maç sayısı: ......

• Fiziksel aktivite katılımı? Evet / Hayır

Tip:.......

Sıklık:.......

Süre:.......

HES KODU BİLGİSİ: ....

9.3. Appendix 3 General Information Form for Students

Öğrenciler için Genel Bilgi Formu

<u>Genel bilgiler:</u>

- Adı ve soyadı:……
- Doğum tarihi/Yaş:……
- Cinsiyet:……
- Boy uzunluğu:…….
- Vücut ağırlığı:……

<u>Genel sağlık durumu:</u>

- Kronik bir hastalık varlığı: Evet (………………………) / Hayır
- Geçirilen ameliyatlar: Evet (………………………) / Hayır
- Geçirilen yaralanmalar: Evet (………………………) / Hayır
- Kullanılan ilaçlar: Evet (………………………) / Hayır
- Son 1 yılda ayak bileği yaralanması geçirdiniz mi? Evet / Hayır
- Alınan Tedaviler: Evet (………………………) / Hayır
- Kronik veya akut ağrı varlığı: Evet (………………………) / Hayır

<u>Fiziksel aktivite bilgileri:</u>

- Fiziksel aktivite katılımı? Evet / Hayır

Tip:……

Sıklık:……

Süre:……

HES KODU BİLGİSİ: ………………………

9.4. Appendix 4 Cumberland Ankle Instability Tool

CUMBERLAND AYAK BİLEĞİ İNSTABİLİTE ÖLÇEĞİ

Lütfen aşağıdaki ifadelerin altında belirtilen durumlardan, size en uygun olan yalnızca 1 tanesini her iki ayak bileği için işaretleyiniz.

		SAĞ	SOL
1.	**Ayak bileğim ağrıyor.**		
	Hiçbir zaman	□	□
	Spor sırasında	□	□
	Düz olmayan zeminde koşarken	□	□
	Düz zeminde koşarken	□	□
	Düz olmayan zeminde yürürken	□	□
	Düz zeminde yürürken	□	□
2.	**Ayak bileğimde güvensizlik hissediyorum.**		
	Hiçbir zaman	□	□
	Spor sırasında ara sıra	□	□
	Spor sırasında sık sık	□	□
	Günlük aktiviteler sırasında ara sıra	□	□
	Günlük aktiviteler sırasında sık sık	□	□
3.	**Keskin dönüşler sırasında ayak bileğimi güvensiz hissediyorum.**		
	Hiçbir zaman	□	□
	Koşarken ara ara	□	□
	Koşarken sıklıkla	□	□
	Yürüdüğümde	□	□
4.	**Merdiven inerken ayak bileğimi güvensiz hissediyorum.**		
	Hiçbir zaman	□	□
	Hızlı indiğimde	□	□
	Bazı durumlarda	□	□
	Her zaman	□	□
5.	**Tek ayak üzerinde durduğumda ayak bileğimi güvensiz hissediyorum.**		
	Hiçbir zaman	□	□
	Parmak ucunda	□	□
	Normal basarken	□	□
6.	**Ayak bileğimi güvensiz hissediyorum.**		
	Hiçbir zaman	□	□
	Yana sıçradığım zaman	□	□

	İleri sıçradığım zaman	□	□
	Zıplayıp yere düştüğüm zaman	□	□
7.	**Ayak bileğimi güvensiz hissediyorum.**		
	Hiçbir zaman	□	□
	Düz olmayan zeminde koşarken	□	□
	Düz olmayan zeminde jog koşusu sırasında	□	□
	Düz olmayan zeminde yürürken	□	□
	Düz zeminde yürürken	□	□
8.	**Ayak bileğim burkulur gibi olduğunda onu engelleyebiliyorum.**		
	Hemen	□	□
	Çoğu zaman	□	□
	Bazen	□	□
	Hiçbir zaman	□	□
	Hiç böyle bir his yaşamadım	□	□
9.	**Ayak bileğim burkulur gibi olduktan sonra, ayak bileğim normale döner.**		
	Neredeyse hemen	□	□
	1 günden kısa sürede	□	□
	1-2 gün içinde	□	□
	2 günden fazla sürede	□	□
	Hiç böyle bir his yaşamadım	□	□
	Toplam:		

9.5. Appendix 5 Tabled Evaluation Form

TABLOLU DEĞERLENDİRME FORMU

Aktif Eklem Hareket Açıklığı Ölçüm Tablosu:

	Dorsifleksion	Plantar Fleksion	Inversiyon	Eversiyon
1				
2				
3				
Ortalama				

Pasif Eklem Hareket Açıklığı Ölçüm Tablosu:

	Dorsifleksion	Plantar Fleksion	Inversiyon	Eversiyon
1				
2				
3				
Ortalama				

Eklem Pozisyon Hissi Ölçüm Tablosu:

	105 °	120 °	130 °	140 °
1				
2				
3				
Ortalama				

Vibrasyon Duyusu Ölçüm Tablosu:

	Medial Malleol	Baş Parmak	Beşinci Parmak
1			
2			
3			
Ortalama			

Kas Kuvveti Ölçüm Tablosu:

	Dorsi fleksion (N)	Plantar Fleksion (N)	Inversiyon (N)	Eversiyon (N)
1				
2				
3				
Ortalama				

9.6. Appendix 6 Ethical Committee Report

T.C. YEDİTEPE ÜNİVERSİTESİ GİRİŞİMSEL OLMAYAN KLİNİK ARAŞTIRMALAR ETİK KURULU		Versiyon No 1.0 Sayfa 1 / 2

KARAR FORMU

22.02.2022

ETİK KURUL BİLGİLERİ	Etik Kurulun Adı	Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu
	Açık Adres	Yeditepe Üniversitesi Diş Hekimliği Fakültesi, Bağdat Cad. No. 238 Göztepe 34728 Kadıköy, İstanbul
	İnternet Sayfası	http://goetik.yeditepe.edu.tr/
	Telefon	0216 363 60 44
	E-posta	goetik@yeditepe.edu.tr

DEĞERLENDİRİLEN BELGELER	Islak imzalı başvuru dosyası, CD'si ve elektronik başvuru	☒
	Araştırma başlığı ve araştırmacıların isimleri	☒
	Başvuru dilekçesi	☒
	Araştırmanın;	☒
	• Niteliği	☒
	• Önemi ve özgün değeri	☒
	• Amaç ve hedefleri	☒
	• Yöntemi	☒
	• Yönetimi	☒
	• Yaygın etkisi	☒
	• Araştırma bütçesi (Mevcutsa)	☒
	• Süresi ve uygunluğu (Zaman cetveli)	☒
	• Kaynakları	☒
	Araştırma izin belgesi / belgeleri	☒
	Bilgilendirilmiş Gönüllü Olur Formu (yapılan araştırmaya özel olarak hazırlanmış)	☒
	Taahhütname-1 Dünya Tıp Birliği Helsinki Bildirgesinin son versiyonunun ve Sağlık Bakanlığı'nın ilgili tüm kılavuzlarının okunmasına dair taahhüt	☒
	Taahhütname-2 Daha önce yapılmış etik kurul başvuruları mevcut olup olmadığına dair taahhüt	☒
	Taahhütname-3 Araştırma sırasında araştırma bütçesinde yer almayan ve gönüllünün kendisine veya Sosyal Güvenlik Kurumuna ek yük getirecek hiçbir işlem uygulanmayacağına dair taahhüt	☒
	Taahhütname-4 COVID-19 hastalarında tedavi yaklaşımları ve bilimsel araştırmalar genelgesi okunmasına dair taahhüt	☒
	Araştırmacıların her birisine ait özgeçmiş formu	☒
	Ek belgeler (Varsa kullanılan ölçek izinleri vb.)	☒

KARAR BİLGİLERİ	Başvuru Numarası	202202159
	Toplantı Tarihi	11.02.2022
	Toplantı Yeri	Çevirim içi (Google Meet)
	Karar No	10

Araştırmanın Başlığı	Üniversite Düzeyindeki Voleybolcuların Ayak Bileği Fonksiyonları ve Postural Kontrol Değişkenleri Yönünden İncelenmesi
Araştırmacılar	Fzt. Ayşem Ecem Özdemir, Dr. Öğr. Üyesi Çiğdem Yazıcı Mutlu

BAŞVURU NUMARASI: 202202159

KARAR 22.02.2022

☒ **KABUL**	☐ **RET** ☐ *KAPSAM DIŞI (GİRİŞİMSEL)* ☐ *BİLİMSEL VE/VEYA ETİK KURALLARA AYKIRI* ☐ *BİR SORUMLU ARAŞTIRMACININ (TEZ İSE TEZ DANIŞMANI), BİR TOPLANTIYA **İKİ (2) ADETTEN FAZLA ÇALIŞMA BAŞVURUSUNDA** BULUNMASI* ☐ *KURUM İÇİ BAŞVURULARINDA **YEDİTEPE UZANTILI E-POSTA HESABI** İLE GİRİŞ YAPILMAMIŞ OLMASI* ☐ *ŞARTLI KABULDE BELİRTİLEN REVİZYONLARIN ZAMANINDA VE/VEYA İSTENİLDİĞİ ŞEKİLDE YAPILMAMIŞ OLMASI*

Yeditepe Üniversitesi Girişimsel Olmayan Klinik Araştırmalar Etik Kurulu adına
Prof. Dr. Didem Özdemir ÖZENEN
Başkan

Araştırmanın Başlığı	Üniversite Düzeyindeki Voleybolcuların Ayak Bileği Fonksiyonları ve Postural Kontrol Değişkenleri Yönünden İncelenmesi
Araştırmacılar	Fzt. Ayşem Ecem Özdemir, Dr. Öğr. Üyesi Çiğdem Yazıcı Mutlu

9.7. Appendix 7 Resume

Kişisel Bilgiler

Adı	Ayşem Ecem	**Soyadı**	Özdemir

Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Yüksek Lisans	Fizyoterapi ve Rehabilitasyon (İngilizce)	Yeditepe Üniversitesi	2020-Halen
Lisans	Fizyoterapi ve Rehabilitasyon	Acıbadem Üniversitesi	2016-2020
Lisans	Rehabilitation Sciences and Physiotherapy - Erasmus+	Gent University	2020
Lise	-	İTÜ GVO Özel Ekrem Elginkan Lisesi	2013-2016

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

Bildiği Yabancı Dilleri	Yabancı Dil Sınav Notu (#)
YÖKDİL (2019)	93,75
IELTS (2015)	7 / C1

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	Süre (Yıl - Yıl)
Araştırma Görevlisi	İstanbul Gelişim Üniversitesi	2021-Halen
Fizyoterapist	Tunalı Spor Kadın Voleybol Takımı (Türkiye Voleybol Federasyonu, 2.Lig)	2021-2022

Bilimsel Çalışmaları

Diğer dergilerde yayınlanan makaleler

Özdemir, A. E., & Kanbur, B. N. (2022). The effect of ecologically based playgrounds on the child's sensory and motor functions. Journal of Human Sciences, 19(4), 582-588.

Uluslararası bilimsel toplantılarda sunulan bildiriler

Feyzioğlu, Ö., Dinçer, S., Özdemir, A. E., Öztürk, Ö. Geriatrik kanser hastalarında kırılganlığın fonksiyonel mobilite ve sağlıkla ilgili yaşam kalitesi üzerine etkisi. II. Uluslararası Gazi Sağlık Bilimleri Kongresi, 2022. İstanbul, Türkiye.

Pes planus'u Olan Genç Yetişkinlerde Miyofasyal Gevşetme Tekniklerinin Denge Üzerine Akut Etkilerinin İncelenmesi: Pilot Çalışma. II. Uluslararası Gazi Sağlık Bilimleri Kongresi, 2022. İstanbul, Türkiye.
Özdemir, A. E., Yazıcı Mutlu, Ç. Relationship between ankle joint functions and postural stability variables of collegiate volleyball players: Pilot study. Spor Yaralanmalarında Kanıta Dayalı Yaklaşımlar Kongresi, 2022. Gazimagusa, Kıbrıs.
Özdemir, A. E., Feyzioğlu, Ö., Dinçer, S., Öztürk, Ö. Onkoloji hastaların yaşam kalitesi düzeylerinin incelenmesi ve semptomların yaşam kalitesi üzerine olan etkisinin araştırılması. XVIII. Fizyoterapide Gelişmeler Kongresi, 2022. Ankara, Türkiye.
Meran, Çağlar, M., Çağlar, E., Kaya, Ö., Özdemir, A. E., Kethüdaoğlu, M. O., Duymaz, T. Pes Planuslu bireylerde dinamik denge değerlendirmesine Y Denge Testinin değerlendiriciler arası ve test-tekrar test güvenilirliğinin incelenmesi: Pilot çalışma. XVIII. Fizyoterapide Gelişmeler Kongresi, 2022. Ankara, Türkiye.

Diğer (Görev Aldığı Projeler/Sertifikaları/Ödülleri)

Egzersize hazır olmak ne demek? Risk faktörleri nasıl ölçülür? – Konuşmacı- 5. Ulusal fiziksel Aktivite Sempozyumu – 25.05.2022 - İstanbul