



T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
DEPARTMENT OF PHYSIOTHERAPY AND REHABILITATION

INVESTIGATION OF FOOT AND ANKLE CHARACTERISTICS IN STROKE PATIENS

MASTER OF PHYSIOTHERAPY AND REHABILITATION THESIS

ELİF DUVARCI, PHYSIOTHERAPIST

İstanbul, 2020



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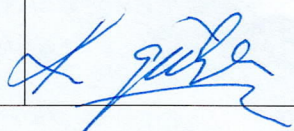
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Bu çalışma jürimiz tarafından kapsam ve kalite yönünden Yüksek Lisans Tezi olarak kabul edilmiştir.

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ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun/...../..... tarih ve sayılı kararı ile onaylanmıştır.

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DECLARATION

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

28.05.2020



Elif Duvacı

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LIST OF SYMBOLS AND ABBREVIATIONS

ADL	Activities of Daily Living
AVM	Arteriovenous malformation
BMI	Body Mass Index
BOS	Base of Support
CNS	Central Nervous System
COM	Center of mass
COP	Center of Pressure
CPR	C-reactive Protein
CVA	Cerebrovascular accident
DF	Dorsiflexion
DM	Diabetes Mellitus
FAC	Functional Ambulation Classification
FFI	Foot Function Index
FPI	Foot Posture Index
F	Frequency
HT	Hypertension
HV	Hallux Valgus
m	Meter
MAS	Modified Ashworth Scale
mm	Millimeter
MPJ	Metatarsophalangeal joint
MMSE	Mini mental state examination
NA	not applicable
ND	Navicular Drop
NH	Navicular Height
p	Statistical significance
PGT	Paper Grip Test
r	Correlation coefficient
RCSP	Resting Calcaneal Stance Position
ROM	Range of Motion
UMN	Upper Motor Neuron
VAS	Visual Analogue Scale
WHO	World Health Organization
°	Degree

ABSTRACT

Duvarci, E. (2020). Investigation of Foot and Ankle Characteristics in Stroke Patients. Yeditepe University, Institute of Health Science, Department of Physiotherapy and Rehabilitation, MSc thesis, İstanbul.

This study was conducted to compare the affected and non-affected foot and ankle characteristics of individuals with stroke with healthy individuals and to investigate the foot-ankle problems and factors related to this problem. Foot-ankle characteristics for individuals with stroke with and without falling history were compared. Total of 48 individuals with 24 healthy individuals with an average age of 69 ± 5.82 and 24 individuals with stroke, the average age of 68 ± 6.94 and ≥ 3 functional ambulation classification and mean time post stroke 7 ± 5.06 was included in this study. 12 individuals with stroke had falling history while 12 individuals with stroke had no falling history. The foot and ankle characteristics of all the individuals participating to this study were evaluated based on 6 parameters which were foot posture, foot range of motion, foot muscle strength, foot sensation, foot functions and foot deformities. All these parameters were compared and the differences between these parameters were analyzed. There was a significant difference in all measurement groups comparing the stroke group and the healthy group ($p < 0.05$). While there was no significant difference for the dorsiflexion angle and foot posture is affected and non-affected foot of the individuals with stroke ($p > 0.05$), the foot was in pronation compared to healthy individuals ($p < 0.05$). Individuals with stroke and with falling history had a higher level of pronation than individuals with stroke and without falling history and individuals with falling history had decreased ankle dorsiflexion joint range of motion ($p < 0.05$). As a result of this study, when the foot and ankle characteristics of individuals with stroke and healthy individuals were compared, changes were observed in these characteristics. It is believed that these changes might affect balance and functional mobility. The importance of evaluating all foot-related parameters to determine the physiotherapy and rehabilitation program of individuals with stroke was emphasized.

Key words: Stroke, Foot and ankle characteristics, Foot problems, Foot posture after stroke

ÖZET

Duvarcı,E. (2020). İnme Geçirmiş Bireylerin Ayak ve Ayak bileği Karakteristiklerinin İncelenmesi Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü, Fizyoterapi ve Rehabilitasyon ABD., Master Tezi. İstanbul.

Bu çalışma inme geçirmiş bireylerin, etkilenmiş ve etkilenmemiş taraftaki ayak ve ayak bileği karakteristiklerini sağlıklı kontrollerle karşılaştırarak belirlemek, ayak-ayak bileğinde meydana gelebilecek problemleri ve bu problemlerle ilişkili faktörleri incelemek için yapıldı. Düşme öyküsü olan ve olmayan inmeli kişiler için de ayak-ayak bileği karakteristikleri karşılaştırıldı. Çalışmaya yaş ortalamaları 69 ± 5.82 olan 24 sağlıklı yetişkin ve yaş ortalamaları 68 ± 6.94 olan, fonksiyonel ambulasyon sınıflamasına göre ≥ 3 skoruna sahip ve inmeden sonra geçen ortalama süre 7 ± 5.06 olan, 24 inmeli olmak üzere toplam 48 kişi dahil edildi. İnme geçirenler 12'si düşme öyküsü olan 12'si düşme öyküsü olmayan bireylerden seçildi. Çalışmaya katılan tüm bireylerin ayak ve ayak bileği karakteristikleri; ayak postürü, normal eklem hareket açıklığı, kas gücü, plantar duyu, ayak fonksiyonları ve deformitelerine bakılarak bu 6 parametre üzerinden değerlendirildi. Tüm bu parametreler karşılaştırılarak gruplar arasındaki farklılıklar incelendi. İnmeli grupla sağlıklı kontrolleri karşılaştıran tüm ölçümlerde gruplar arası anlamlı farklılık vardı ($p < 0,05$). İnmeli bireylerin etkilenmiş ayaklarıyla etkilenmemiş ayakları arasında dorsifleksiyon açısı ve ayak postürü açısından anlamlı bir farklılık olmayıp ($p > 0,05$), sağlıklı bireylere kıyasla ayakları pronasyonda bulundu ($p < 0,05$). Düşme öyküsü olan inmeli bireylerin ayakları düşme öyküsü olmayan inmelilere göre daha yüksek derecede pronasyona sahipti ve düşme öyküsü olanlarda ayak bileği dorsifleksiyon eklem hareket açıklığı azalmıştı ($p < 0,05$). Çalışmanın sonucunda, inme geçirmiş bireyler kontrol grubuyla karşılaştırıldıklarında ayak ve ayak bileği karakteristiklerinde değişimler gözlemlendi. Bu değişimlerin denge ve fonksiyonel mobilitayı etkileyebileceği düşünülmektedir. İnmeli bireylerin fizyoterapi ve rehabilitasyon programlarının belirlenmesinde ayağa ilişkin tüm parametrelerin ayrıntılı değerlendirilmesinin önemi vurgulandı.

Anahtar kelimeler: İnme, Ayak ve ayak bileği karakteristikleri, Ayak problemleri, İnmeden sonra ayak postürü

1. INTRODUCTION AND PURPOSE

There are cases where cerebrovascular diseases cause stroke in patients and lead to problems in the daily tasks of these individuals. Cerebrovascular diseases cause stroke in patients, these individuals have problems in their daily tasks. This is mainly caused by the problems in motor, sensory, cognitive and language systems. On the other hand, patients experience a lower level of activity and functional independence as the gait is lost (1). Patients with stroke often have problems with gait. This problem has characteristics such as slow gait cycle, slow gait speed, paretic and non-paretic side stride differences, long swing phase as well as short stance phase (2). The ankle joint plays a key role to absorb the impact, move the body forwards and to maintain the balance as the ankle strategy (3). Gait disorders occur due to ankle joint movement problems (4).

Foot posture has an important role for standing, walking and balance (5). With the increasing age, certain physiologic changes occur in foot structure (6,7). Pain, increased pronation, lower ankle motion range, lower first metatarsal phalangeal joint motion range, more common hallux valgus problems, toe sensation problems and lower toe strength are some of the problems in the foot related to ageing process (7,8). In general, problems in the foot can be linked with walking pattern changes, issues with balancing skill and higher falling risks (8). Therefore, it is important to express foot related posture and biomechanical properties. There are only a few studies analyzing foot and ankle characteristics of stroke patients in the literature. Forghany et al. stated that stroke patients experience decreased ROM in different foot segments and planes and there is a higher pronated foot position (9). Another study investigating the foot posture by using the foot posture index in stroke patients found that stroke individuals with abnormal foot posture were more common than the supination of the pronation (10). On the other hand, Gwon et al. expressed that FPI scores indicated higher supination on the affected foot and found that there is a connection between supinated foot postures and higher spasticity level (11).

There are various objective and subjective tests, methods and questioning surveys to assess the foot (12,13). However, it is challenging to analyse the shape of the foot in-clinic field as required equipment is expensive and the procedure is time-consuming.

In this study, the purpose is to investigate participant foot shape by using foot posture index (FPI) which is a simple foot deformity measurement for stroke patients at

clinical settings. To understand how stroke affects foot joint deformity in hemiplegic patients, modified Ashworth scale (MAS), navicular drop test (NDT) and resting calcaneal standing position test (RCSP) is aimed to be applied as other current test methods. These methods do not require a high number of equipment or time and findings are believed to act as a guide for future treatment strategies.

It is known that foot problem and falling incidences are high in the old population. At the same time, individuals with stroke have a higher risk compared to individuals in the general population (14,15). Current studies stated that there is a correlation between the foot and ankle properties and falling in old population and individuals with stroke have higher falling risk. Additionally, only a few studies have investigated the foot and ankle properties of chronic individuals with stroke. Furthermore, it is unclear whether foot and ankle problems contribute to falling risk in the stroke population. The purpose of this study is to compare foot posture index in individuals with stroke for certain anthropometric measurements related with the foot, analyses the factors affecting structural deformities in foot joint and to investigate the impact of such structural foot problems in individuals with stroke on falling. Since there are few studies analyzing structural foot problem of individuals with stroke in the literature, obtained results can have clinical contributions on physiotherapy and rehabilitation practices.

Based on this information, the hypothesis for the planned study are as follows:

There are differences between individuals with stroke and healthy control group in terms of foot and ankle characteristics.

There are differences between stroke patients with falling history and without falling history in terms of foot and ankle characteristics.

2. LITERATURE REVIEW

2.1. Stroke

2.1.1. Definition of Stroke

According to the World Health Organization, stroke defined as a clinical syndrome with rapidly settled symptoms and findings for focal cerebral function loss without any reasons other than vascular reasons. Symptoms last for more than 24 hours or might lead to death (16). The syndrome is indicated within a wide range from complete recovery in one-two days, partial recovery, heavy disability and death (17). Head trauma (subdural hematoma), brain tumor, central nervous system infections (encephalitis, abscess), postictal paralysis, complicated migraine, metabolic disorders (hypo- and hyperglycemia), temporary ischemic attack (transient ischemic attack) with similar symptoms to stroke are excluded from this classification and this decreased the total number of stroke disease in epidemiologic studies (18).

Stroke as an indicator of a neurovascular disease is a clinical case with voluntary action loss on the cross-body, sensory loss and various neurologic symptoms due to a lesion in the brain (16).

2.1.2. Epidemiology

Stroke is the third most popular cause of death after heart disease and cancer in developed countries and the second most common cause of death around the world. Stroke as the most important morbidity and long-term disability source in adulthood is the second disease that caused dementia after Alzheimer's disease (19). There are differences between countries and female/male ratio for stroke incidents (20).

Studies showed that annual stroke incidents in Europe in 55-64 years old average is 1.7-3.6/1000 people. In the US, this ratio was reported as 120-200/100,000 (27). Based on these ratios, 80,000-100,000 per year acute stroke incidents can be seen in our country (21).

Generally, annual stroke incidents per age are 1.7-3.6/1000 for 55-64 years old, 4.9-8.9/1000 for 65-74 years old and 13.5-17.9/1000 for 75 years old and above. Stroke incidents form only 35% of all strokes under 45 years old. 55-64 years old stroke incidents in women are 2-3 times lower than men. This difference decreases in 85 years old (22).

Hospital-based Stroke Database that analysis general properties and risk factors of the stroke patients showed 77% ischemic stroke and 23% hemorrhagic stroke. The most important reason for hemorrhagic stroke to be higher in Western societies is the lack of hypertension knowledge as the major risk factor, interruptions to participate in treatment and uncontrolled lifestyle. According to Stroke Database, ischemic strokes are more common in men except for 40 years and below and 75 years and above age group. In hemorrhagic stroke, men have a higher rate for 40 years and below and 75 years and above age group (23).

Recent epidemiological studies showed that stroke-caused death rates are decreasing. This is mainly explained by higher diagnosis and advanced clinical knowledge. Decreased stroke-caused deaths lead to higher general life rate and lower stroke incidents (24). Epidemiological studies showed that life expectancy increased after stroke. This is mainly caused by controlling preventable risk factors and developed treatment methods and care conditions. However, the stroke prevalence is expected to increase due to higher older population in developed countries and better treatment of infection and other death reasons in developing countries (24, 25).

2.1.3. Risk Factors

Stroke risk changes based on the number of risk factors in an individual, independent risks of these factors and relative risks of these factors. Today, the majority of stroke risk factors are defined and showed to be treatable. However, necessary and effective prevention methods are not applied sufficiently. The most effective way to decrease the effects of stroke on public health due to high mortality rate, long-term disability and higher probability to repeat after the first stroke seems like preventing the risk factors. Since it is not possible to completely eliminate stroke, education and patient screening methods should be developed and high-risk individuals should be closely monitored and treated to decrease the negative consequences of stroke (26). The highest risk for the stroke to repeat is in the post-acute period. While the risk to repeat in one year is 8-12%, the risk to repeat in five years is 25-42% (26,27). Therefore, knowing the risk factors is important to decrease both first and repetitive strokes.

There are no medical treatments to reverse the neurologic damages caused by the stroke. Therefore, knowing the risk factors and using these factors to prevent stroke is

important (28). When considered individually, age is the main risk factor and interaction with other risk factors and prevalence for public health should be considered (34). In a stroke, risk factors are divided into two as changeable and unchangeable risk factors (16, 26, 28).

2.1.3.1. Nonmodifiable Risk Factors

Nonmodifiable risk factors are the age, gender, ethnicity and family cerebrovascular disease history. It is recorded that stroke risk increased as age increased. In every decade after fifty-five years old, this risk is twice as higher. Stroke is higher in men than in women. As the elderly population increases, stroke in women started to be more dominant at higher ages. At the same time, different stroke studies in our country show that women are more dominant. A study by atherosclerosis risk committee (ARIC) identified that stroke risk in black people is 38% higher than Caucasians (29).

One of the other nonmodifiable risk factors is heredity (Apo B, ACE gene polymorphism, thrombophilia). Various elements in family history play a role as a risk factor. At the same time, some factors might be a similar lifestyle, eating habits and hereditary properties (30). Stroke risk in monozygotic twins is higher than dizygotic twins (31).

2.1.3.2. Modifiable Risk Factors

2.1.3.2.A. Treatable Risk Factors

These are stated as hypertension (HT), diabetes mellitus (DM), hyperinsulinemia and glucose intolerance, heart diseases, hyperlipidemia, smoking, asymptomatic carotid stenosis, transient ischemic attacks and sickle cell anemia.

2.1.3.2.B. Untreatable Risk Factors

These are stated as nutritional habits, alcohol use, oral contraceptive use, physical inactivity, obesity, hyperhomocysteinemia, hormone use, fibrinogen height, inflammation (CRP elevation), hypercoagulability (polycythemia vera, protein C and S deficiency, lupus anticoagulant, anticardiolipin antibodies).

2.1.4. Cerebrovascular Anatomy

Blood is supplied to the brain with two artery system. Carotid system supplies approximately 70% of the blood to the brain and 30% is supplied with vertebroplasties. In these two major vascular systems of the brain, internal carotid are formed from vertebral arteries truncus brachiocephalic on the right side and arteria subclavian existing directly from aorta curve on the left side.

Blood flow to cerebral hemisphere other than occipital lobe are supplied with carotid internal branches, from supratentorial structures with cerebral trunk and cerebellum in the infratentorial region and thalamus blood flow from occipital lob is supplied from vertebral artery and branches. There is a high number of anastomosis possibilities between the arteries providing brain circulation. Collateral circulation between both carotid system in the intracranial region, vertebroplasties system and carotid system that are activated when necessary are supplied with Willis polygon (32, 33).

2.1.5. Classification

Based on the formation mechanism, stroke is divided into two as hemorrhage and ischemic (28).

Ischemic type (Cerebral infarct) (84%) consists of thrombotic type (53%) divided into major vascular occlusion (34%) and hypertensive lacuna (19%) and embolic type (31%) divided into cardiac (19%) and non-cardiac (12%). Hemorrhagic type (16%) and divided into hypertensive intracerebral hemorrhage (10%) and subarachnoid hemorrhage (6%). There are also aneurismal hemorrhage and arteriovenous malformations (AVM).

2.1.5.1. Thrombotic CVA

This situation which is the most common type of stroke occurs due to major blood vessel atherosclerotic occlusion of carotid or middle cerebral artery. Thrombotic occlusion occurs in an increasing process and deficit develops slowly. Symptoms advanced in hours and days (34). Thrombotic CVA frequently occurs during night sleep or rest. This is often identified with weakness or loss of function when patients try to get up from the bed. Atherosclerosis often happens on the major vessels. Therefore, ischemia tends to expand after thrombotic stroke and patients get worse in the following processes (16, 35-36).

2.1.5.2. Embolic CVA

Emboli might occur a thrombus developing in the heart, heart valves or major extracranial artery. Cerebral emboli reasons are cardiac which are atrial fibrillation, other arrhythmias; mural thrombus-new myocardial infarction, hypokinesia, cardiomyopathy; bacterial endocarditis; valve implant; non-bacterial valve vegetations; atrial myxoma; Major vascular which is atherosclerosis of the aorta and carotid arteries and paradoxical which is peripheral venous embolism with right-to-left cardiac shunt.

Clinical neurologic loss shows a rapid start. Neurologic symptoms can rapidly get better after emboli lysis and breaking or arterial bleeding in the lesion can occur when there is reperfusion of the infarct region. This might sometimes worsen neurologic charts (37).

2.1.5.3. Lacunar CVA

These are small, limited lesions with the largest 1.5 cm diameter that develop due to deep branch obstruction supplying blood to subcortical areas such as lacunar infarct basal ganglion, thalamus and cerebral trunk. The lacunar infarct is especially closely related to HT and DM. There is a gradual starting history and previous temporary ischemic attack history similar to cerebral thrombosis. The clinical outlook is often complex due to multiple lesions. Neurologic recovery is fast and early in lacunar infarct (16).

2.1.5.4. Hemorrhagic CVA

Intracranial hemorrhage is spontaneous intracranial hemorrhage mainly occurs in deep, small, penetrant artery region. If there is occlusion rather than bleeding in the same arteries, this results in lacunar stroke. It is believed that bleeding occurs due to rupturing microaneurysm (Charcot-Bouchard aneurism) in hypertensive patients. While the lesions are mainly seen in putamen or thalamus, they can also develop in the cerebellum. Clinical start of this bleeding is dramatic which leads to intense sudden headache in a normal individual and major neurologic losses. In the majority of the patients, consciousness gradually breaks down and this is followed by coma. Spontaneous intracranial bleeding is one of the most known complications of anticoagulant treatment. Other reasons might be trauma, vasculitis and bleeding in the tumor (38). Acute mortality is high but patients

surviving intracerebral bleeding often show fast neurologic recovery in two to three months after hemorrhage (39).

Subarachnoid hemorrhage, this happens with saccular aneurism or AVM rupture. Saccular aneurism rupture leads to a highly intense headache and observed with acute unconsciousness. Focal neurologic changes or coma might occur. Saccular aneurism is mainly in anterior of Willis polygon. AVM which is commonly seen at the twenties and thirties which is at the earlier stage of life compared to aneurism is formed from intertwined vascular tissue network and it is a congenital structure with multiple arteriovenous fistulae and leading to arterial-venous blood shunting (40). In almost half of the cases, the first clinical symptom of the lesion is bleeding. In approximately 1/3 of the patients, AVM occurs with seizures or chronic headache (41).

2.1.6. Clinical Features and Impact of Stroke

Stroke might show different clinical features; this mainly depends on lesion site and scope (42). Stroke can cause damages in different mechanical aspects such as movement, sensation, swallowing as well as affective aspects such as sensation, emotion, cognition, communication and continence. These problems can occur at the same time or independent. In some cases, damage or impairment in one of these aspects can have an effect on the other aspects as well. These impairments caused by the stroke reduced well-being as well as other social skills and social participation.

The main driver of the rehabilitation process in case of stroke are the desire to walk in a safe and independent ways by the patients at home environment as well as outdoors (43). Studies reported that 80% of individuals who have suffered a stroke are able to walk independently (44). On the other hand, among those individuals who are able to walk again, one third fear to walk without supervision in social setting (45).

The analysis of different parameters shows that stroke might have higher effect on both walking and walking function. The studies have reported that stroke might lead to balance impairment, lower speed of walking, walking few distance, higher falling incidents and lower community and social integration (46).

Clinical studies and theoretical studies have considered gait as well as post-stroke walking changes in lower limb gross motor performance to handle these problems (47).

There are few studies on foot/ankle and decreased foot/ankle function in stroke patients (47). An individual contact with the ground by using the foot and ankle complex. This unit is important to sense and react to the motion of the body and the ground. Furthermore, this unit helps supporting the changes in surface characteristics. This complex enables movement and keeping the balance in the functional weight bearing process. However, compared to impairment in the upper limb, impairments in the lower limb indicate restriction better. Yet, there are only few studies on the role of foot and ankle. Additionally, the rehabilitation need for foot and ankle impact and health needs are not considered (48). Therefore, to better treat stroke patients, there is the need to develop suitable and targeted rehabilitation care that covers different disciplines.

2.2. Foot and Ankle Anatomy

The structure of foot and ankle ensures necessary stability to carry the body at an upright position without high muscle activity. At the same time, these structures control the bodyweight on the stable foot on the ground and act as a rigid lever at the pushing phase. Ankle directly transfers the force from the lower extremity to the foot and transfers the opposite forces to the upper sections. In the human body, the foot is an extremely important structure with 7 tarsal (talus, calcaneus, cuboid, navicular, 3 cuneiforms), 5 metatarsal bone, 14 finger bones and 33 joints. All bones forming the foot divide the foot into 3 parts as anterior, medium and posterior. Talus and calcaneus forms posterior segment, navicular, cuboid and 3 cuneiform bone forms medium segment and metatarsus and phalanx form anterior segment. These sections are used for showing the deformity and loss of functions (47).

Front Foot consists of five metatarsal and 14 phalanx bones. While the anterior foot is responsible for rapidly and biomechanically pushing the ground during oscillation phase during walking, the posterior foot is responsible for ensuring stability on dynamic condition (47).

The medium foot consists of five metatarsal bone (navicular, cuboid, 3 cuneiforms) and two joints (Lisfranc and Chopart). While navicular has the connection location for middle foot medial and posterior tibialis tendon, middle foot consists of horizontal and longitudinal arcs distributing the bodyweight during movement (48).

Posterior Foot Talus and calcaneus are bone structure forming the posterior foot. Calcaneus is the largest and strongest bone of the foot complex. Posterior foot is a structure consisting of soft tissue, joint and bones to help to move by carrying bodyweight. Posterior foot ensures foot stability. Weight is equally distributed to both foot in a standing individual and 60% of the weight is on the heel and the remaining 40% is carried by anterior foot. When there is no load on the foot, the foot contacts the ground on three different points. These points are calcaneus tubercula, primer and fifth metatarsus (47,49).

2.2.1. Foot and Ankle Joints

Talocrural Joint: Ankle joint is classified as a modified hinge-type synovial joint and consists of tibiotarsi, fibula, distal tibiofibular. This is a hinge-type joint and enables sagittal surface plantar (50-degree) and dorsiflexion (20-degree). Since the joint axis is oblique, in addition to sagittal surface movement, there are talar rotation, fibular sliding and rotation movement (49).

Distal Tibiofibular Joint: Since this joint enables well stabilization with fibrous or syndesmosis joint, there is no osteokinematic movement and only sliding movement is permitted. This joint plays an important in ankle stabilization (47,48).

Subtalar Joint: This is an oblique axis joint forming two different points of talus and calcaneus and this axis is positioned with 42° slope at the sagittal plane and 16-23° slope at the transverse plane with anteromedial deviation. Subtalar joint movements are pronation and supination (47,49). These movements occur at the orthogonal surface to the oblique axis. The subtalar joint enables front foot mobility with its axis. Studies reported that subtalar joint has a low contribution to plantar flexion and dorsiflexion movement, on the other hand, high contribution to inversion/eversion and abduction/adduction movement. Subtalar joint moves linked with the longitudinal axis and enable more inversion and eversion movement. Both subtalar and midtarsal joint ensures inversion and eversion movement and transfers load from posterior foot to medium foot (47,48). When the subtalar joint is in pronation, internal rotation in the talus and when the subtalar joint is in supination, external rotation in talus makes the foot to have a flexible position during oscillation phase (49).

Midtarsal Joint (Chopart Joint): This is a functional joint between back foot (talus and calcaneus) and middle foot (navicular and cuboid). The main duty of this joint is to

preserve the contact of the front foot with the ground when the contact of the back foot is cut during walking. This joint has two movement axis. On the longitudinal axis, eversion and abduction or inversion and adduction movements occur. On the oblique axis, the joint contributes to dorsiflexion and plantar flexion movements (49). Midtarsal joint and subtalar joint movements are interrelated. Subtalar joint pronation makes calcaneocuboid and talonavicular joint axis to parallel form. Midtarsal joint also has pronation. Pronation of both of these joints lead to medial longitudinal arc flattening and the foot becomes more flexible. Supination on subtalar joint disrupts this parallel form, arc raises with midtarsal joint supination and foot becomes more rigid (50).

Tarsometatarsal Joint (Lisfrank Joint): In medial, 3 cuneiform bone, first 3 metatarsals and in lateral, cuboid bone 4th and 5th metatarsal are united (50).

Metatarsophalangeal Joint: This is a two-axis joint between the metatarsal distal proximal phalanx and proximal tips. Dorsiflexion, plantarflexion, abduction and adduction movements occur (50).

Interphalangeal Joint: This is a hinge-type joint between proximal and distal phalanx bones of toes and enables flexion and extension movements (50).

2.2.2. Foot Arcs

The harmony of foot bone complex occurs with transverse formed with tarsal, metatarsal bones and ligament and two longitudinal arcs. These support arcs increase speed and agility during walking by distribution body weight. Arcs act as a rigid lever to ensure flexibility and suitable mobility to fit different surfaces.

Medial Longitudinal Arc: Medial longitudinal arc consists of calcaneus posteromedial, talus, navicular, 3 cuneiform and 1st, 2nd and 3rd metatarsal bones. Apex is navicular and maximal height is measured 1518 mm from the ground. Navicular has an important function for foot posture and navicular vertical height is extremely important to determine arc height. It is supported by tibialis anterior muscle, tibialis posterior muscle, plantar calcaneonavicular (spring) ligament and plantar fascia. It provided the foot with the capacity to absorb some of the increased shock caused by upright striding. The transformation of the grasping function of the medial rays of our primate ancestors into

the plantigrade propulsive feet of modern man was clearly a seminal event in prehuman evolution.

Lateral Longitudinal Arc: This arc starts from postero-lateral of the calcaneus and formed by cuboid 4th and 5th metatarsal bones. It is an apex cuboid and height from ground is measured maximum as 3-5 mm (47,50).

Transverse arc: This arc consists of three sections. Anterior transverse arc lies along with 1st and 5th metatarsal capitulum and supported by intermetatarsal ligament and transverse capitulum of adductor hallucis muscle. Mid transverse arc formed by three cuneiform and cuboid bones is supported by peroneus longus muscle. Posterior transverse arc is between cuboid and navicular and supported by tibialis posterior muscle (49). Arc height can vary due to muscle dysfunction or muscle imbalance. The plantar fascia is strained with metatarsophalangeal extension at the end of the standing phase, joints are locked and the collapse of the medial longitudinal arc is prevented. This is called “windlass” mechanism (50)

During static standing, bodyweight distribution on planter surface varies and during walking, plantar pressure on the foot is higher than static standing. During toe lift in walking, anterior foot contacts with the ground, pushes the body forward and the highest pressure is on metatarsal (48).

2.2.3. Foot – Ankle Dynamic Biomechanics

Brockett and Chapman showed that there is a dorsiflexion moment on ankle movement in the form of gait cycle when the heel is pressed. As there is eccentric contraction of the dorsiflexor, there foot rotary movement is controlled. This acts as a barrier for the foot to slap. As dorsiflexor contracts eccentrically, plantar flexion moment is created and there is a forward progression. Then, there is an on-going plantar flexion moment from concentric contraction of plantar flexors to toe (51). Although the speed of the walk changes, kinetic pattern created by the ankle is the same. However, there is an increase in the magnitude. Gait cycle include two different stages which are Stance phase and Swing phase. When the heel hits the ground, the stance phase will start. This phase continues until the toe leaves the ground. In the whole gait cycle, this stage corresponds to 60-62%. This phase has three different sub-phases.

1. Controlled dorsiflexion sub-phase represent 38% of the cycle. This sub-phase starts when the foot is at flat position and continues until maximum dorsi flexion

2. Controlled planter flexion sub-phase represents 12% of the cycle. This sub-phase starts when the heel hits the ground and the phase is completed when the foot has flat position

3. Powered plantar flexion sub-phase represents 10-12% of the cycle. This sub-phase starts with maximum dorsi flexion and ends when the toe no longer contacts with ground. When the foot is off the ground, swing phase starts. This phase ends when the heel of the same foot hits the ground. This phase represents 40% of the cycle (51).

2.2.4. Function of Foot in the Gait

Human movements are highly linked with the ankle and the subtalar joints. Shiegler, Chen and Shneck showed that in addition to ankle and subtalar joints, internal/external foot ankle movements also benefit from ankle and subtalar joints (52). The foot ankle rotates on three different points of sagittal plane in three different forms.

When the heel is in contact with the floor, the foot is put down with the help of this structure. This case covers the swing phase until the phase where the foot is flat or grounded. When the foot is on the ground, the ankle joint rotates to continue forward motion. With this movement, there is an advancement of the shank. Metatarsophalangeal joint rotation generates power at push off (53).

All joints have the possibility to have 6 degrees of freedom and 3 rotations at plane. These degrees of freedom are abduction-adduction, internal-external and Flexion-extension and rotations are 3 plane rotations as medial-lateral, compression-distraction, anterior-posterior (54).

2.2.5. The Role of Foot in Balance

The foot is an important supporting surface for standing and walking. The foot acts as a sensing organ in low extremity muscle activation regulation and providing sensual input needed for this regulation (53). In standing position, necessary postural control to keep the gravitational center at the support surface and small postural oscillations created for balance from foot and ankle are compensated by the ankle (54). It

is known that mechanoreceptors in foot complex provide “sensorial feedback” for balance (107). Pressure differences in plantar pressure receptors inform the body about the vertical position of the gravitational center compared to the support surface. If equal pressure distribution of the plantar is disrupted and the pressure on a foot increases, extensor muscles tonus on the given extremity increases and flexor muscle tonus of the opposite extremity increases. Thus, falling is prevented while standing is continued. Additionally, if there is a decreased sense of plantar, it is seen that this situation disrupted the balance (54).

2.2.6. The Importance of Foot and Ankle Function

The foot and ankle form a unit with complex and articular structure. In biomechanical terms, the foot consists of two purposes which are body weight support as static function and moving the body forward as dynamic function (55). The ankle enables the foot to contact the surface by acting as a kinetic connection for the foot and the lower limb. The foot has different properties to support different functions such as absorbing shocks and supporting propulsion for locomotion.

The foot and ankle act as main units to spread and propagate the forces arising from ground contact. These forces are shear, rotatory, tensile and compressive forces. In this sense, both foot and ankle are considered as the final units of the kinetic chain (56). Both foot and ankle can bear up to 13 times of the human weight in the running process for the control of the posture and oscillation which is an additional property to absorbing the ground shock (57).

Body oscillation is represented as an inverted pendulum where the pivot point is the ankle joint (58). Therefore, the center of the mass (COM) of the body can be followed and controlled by using the feet and center of pressure movement (COP) (59). The activation of ankle plantar flexor/dorsiflexor muscle enables to balance COM in back and forward movement. High COM movements can be made with small ankle movement or contraction.

Another property of the foot and the ankle is the ability to adapt locomotion and stance changes when COM moves. When the foot contacts with the surface for the first time, the main task of the foot is to absorb the shock, decrease the speed of the movement

in the downwards direction, balance and weight bearing function and preserve the progressive movement (60).

Following this first contact with the ground, the foot tries to contact with the ground at the maximum extend with plantar flexion controlled eccentrically (1st rocker). At this point, body can move forward (2nd rocker) with ankle dorsiflexion as the foot acts as a support. Fast ankle plantarflexion following this step enables the body to move forward in stance phase (61).

When standing, the foot and ankle should match each other since energy conservation is required at gait by storing and providing somatosensory information is provided by structural foot deformations (62). Ankle dorsiflexion decreased the relative leg length for suitable toe clearance at mid-swing phase. This increased the energy efficiency with lower knee and hip flexion requirements. Toe clearance in people with ankle dorsiflexion problems might be achieved with knee flexion increase as well as external hip rotation or tilting the pelvic (63).

Therefore, segments and joints should work together and have high impact on lower limb and surface to achieve highly efficient functions of the foot and ankle (8).

If this unit experienced any damage or impairment, several functional processes might be hindered. Studies on individuals with old age have showed a relationship between ankle dorsi/plantar flexor strength and postural sway (16), walking speed (64), changing position from sitting to standing (63) and to stoop, to crouch and to kneel (65). The balance can be afflicted when the sagittal plane and frontal plane of the ankle motion is decreased (66). On the other hand, falls are predicted by ankle dorsiflexion and plantar tactile sensing decreases (16). Spink et al worked on 305 participants between 63-95 years old and showed that hallux plantar flexor strength and ankle inversion/eversion range were the main factors determining the balance and functional skills of the elderly individuals.(67) Deshpande et al worked on 799 individuals with old age for foot and ankle somatosensorial and indicated that foot sole tactile sensation and ankle proprioception were able to indicate the balance performance at the standing position the balance performance at the dynamic position as well as the speed of gait (68).

2.2.7. Foot-Ankle Characteristics and Evaluation

Foot and ankle characteristics were tested six domains: foot posture, foot sensation, foot ROM, foot strength, foot function and foot deformity.

1. Foot Posture

Foot Posture Index

It is an easy, valid and reliable method for individuals with stroke where different criteria of foot posture are assessed in a total of 6 items as front foot and back foot and inform about pronation supination level with the single numerical result (69). This test is conducted at the static and comfortable standing position by a therapist based on observation and palpation. It is important to have correct information about anatomic localization, palpation and observation for the therapist to obtain correct and reliable results. Each criterion is scored between -2/+2 and total score of the test is calculated. Based on the obtained scores, 0-5 range is assessed as normal, 6-9 range as pronation, 9-12 range as high pronation.

Foot Posture Index sub-topics:

- Talar head palpation
- Supra/infra malleolar inclination
- Calcaneus position at the frontal plane (eversion/inversion)
- Medial view of talonavicular joint
- Medial longitudinal arc height
- Front foot abduction/adduction (70).

Navicular Height and Navicular Drop Test

When the individuals are standing in a comfortable position, the height of navicular tubercula from the ground is expressed as “navicular height”. The individuals stand while navicular height (NH) measurement of navicular tuberosity is palped and marked at standing position. Then, a measuring tape is used for measuring the height between the ground and navicular tuberosity.

Navicular drop (ND) is reported as the difference between navicular tubercle height determined with palpation in foot subtalar neutral position and sitting with 90 degrees position between hip and knee without putting weight on the foot and navicular

tubercle height differences in standing position with weight on foot. The navicular drop was first defined by Brody (68). Brody, Beckett, Mueller reported navicular drop upper limit as 15mm,13mm,10mm respectively (68,69). Brody classified values under 10mm as normal and value above 15mm as abnormal. Adhikari et al. investigated the effects of age, gender, height, weight, body mass index (BMI) and foot length in adult female and male on navicular drop value and found no significant relationship between BMI and navicular drop (70). Navicular drop in men was found higher than women and it is believed that this was related to the foot length.

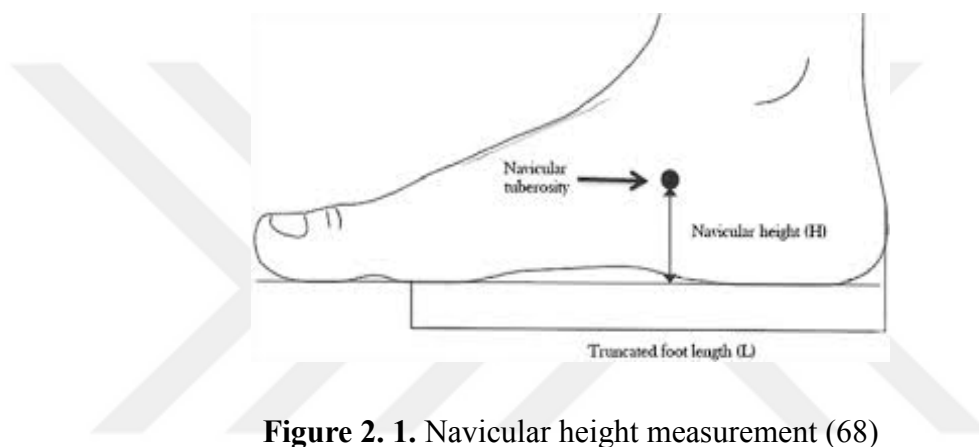


Figure 2. 1. Navicular height measurement (68)

Resting Calcaneal Stance Position (RCSP)

RCSP, defined as the angle between the heel bisection and a vertical line, is technically convenient and has been widely used in ankle deformity orthopedics has validity and reliability for adults (19,20).

The RCSP angle measurement was performed as follows. The patient is first relaxed and made to lie in the prone position on the examination table. Second, the physician plots three dots vertically on the foot: the upper, middle, and lower dots, bisecting the calcaneal bone using a bimanual technique; those dots are connected by drawing a line. Third, the patient is relaxed and positioned standing on his/her feet. Fourth, the physician measures the angle between the vertical and the ground and the calcaneal bisection line.

2. Foot Sensation

10g retractable monofilament was adopted to evaluate 1st MPJ plantar sensation. Online American College of Physicians Clinical 2007 guidelines was adopted the foot care of the diabetic patients to identify bowed and sensitivity with yes and no answers where monofilament was used. The American College of Physicians Clinical published and updated version when the process to collect data was finished (71). Monofilament test has validity and reliability has for adults. Four test sites for each foot is provided as a recommendation (1st, 3rd, and 5th metatarsal heads and plantar surface of distal hallux).

In the examination process, the basic yes and no questions to patients are asked during monofilament application to test site. In this application, patients should feel pressure and also identify the pressure on the correct test area of the foot.

3. Foot ROM

First metatarsophalangeal joint and the ankle joint are the two most important joints in elderly people. These joints act in propulsion for main sagittal plane pivots and as the age increases, these joints reduce significantly. Universal goniometer is selected for active ankle dorsiflexion ROM measurements. During measurements participants put their knee on a stool to rest with anatomical and marks (72). Furthermore, Hopson (73) methods for non-weight bearing position is adopted for active 1st MPJ extension ROM measurement (74). There will be three ROM measures and after these three measurements, the mean of three measurements will be computed.

4. Foot Strength

The paper grip test is useful clinical muscle test, which was first developed to assess muscle paralysis in the feet of leprosy patients and has reliability and validity for adults (73). To perform the test, the patient is seated with their hip, knee and ankle at 90° and is instructed to use their toe muscles to push down on a piece of cardboard while the clinician stabilizes the ankle and forefoot and attempts to slide the cardboard away from the toes. The test is performed three times for the hallux and lesser toes.

5. Foot Function

Foot function is evaluated Foot Function Index. (FFI) (74) provides visual analogue scales for measuring foot pathology impacts on function as the pain, disability

and activity limitations are quantified each sub-scale (in this index, as the scores are higher, the foot function gets worse).

FFI is used in case of foot complaints and foot function problems for measuring pain and mobility limitation. The scale has validity and reliability for adults 3 scales and total of 23 items which are limitation (5 items), pain (9 items) and disability (9 items). The scale is scored with horizontal line (10 cm) VAS that does not have any sub-divisions. The limitations are scored between “never” and “always”, the pain is scored between “intense pain” and “no pain” and the disability is scored between “no difficulty” and “impossible”. During scoring, participants scores limitation, pain and disability for foot complaints on the horizontal line. The scale is scored between minimum of 0 and maximum of 9. Patients should mark “NA” when they do not experience function loss due to foot complaint. Any item marked as “NA” is not included in the evaluation. The scores are calculated by summing all item scores and dividing this sum to maximum possible sum and multiplying this result by 100. This calculation gives the mean scale score. The scale ranges between 0 and 100 where the limitation, pain or disability increases as the score is higher.

6. Foot Deformity

Hallux valgus is a progressive front foot problem commonly seen in adults. This foot deformity starts with hallux lateral deviation and metatarsal primus varus bone medial deviation and seen as progressive subluxation of primal metatarsophalangeal joint (MTJ) (75,76). Plantar foot pain, MTJ medial pain, due to joint deformation and pain when weight is lifted are the symptoms of hallux valgus (76).

There are many preparatory factors for hallux valgus. These factors are divided into two as intrinsic and extrinsic. Shoes and excessive body weight form the extrinsic factors. Genetic factors, gender (female>male), age, ligamentous laxity, other foot deformities (pes planus, hindfoot pronation, metatarsus primus varus), neuromuscular diseases, Achilles tendon tension are the intrinsic factors (77). Posture, joint kinematic and plantar pressure changes with age create a great risk for hallux valgus (78).

Hallux valgus can be easily graded in the clinical environment using the Manchester scale has validity and reliability for adults, is applied to clinically grade hallux valgus. This test includes four standardized photos which shows the deformity (75).

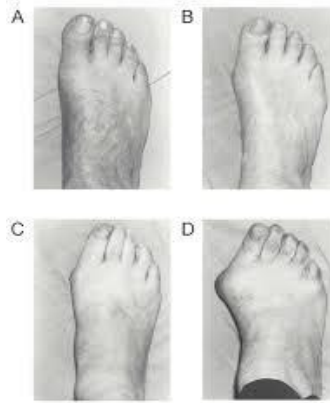


Figure 2. 2 Manchester Scale (75)

2.3. Aging and Changes in Aging Foot

Aging as a complex and changing phenomenon is an indispensable and natural part of life. (WHO, 1998). Aging is a biologic, psychologic and sociologic regression period and an inevitable process that covers irrevocable physical and functional negativities in cells, tissues, organs and systems of the living beings. (77).

World Health Organization (WHO) defined aging as 65 years and above and divided ageing process as 65-74 years old as young elders, 75-84 years old as medium elders and 85 years old and above as advanced elders. (78).

Aging effects physical mobility and life capacity and change the structure and physiology of foot and ankle complex. These changes might be caused by genetic tendency, systemic disease, insufficient foot care, unsuitable shoe, long-term physical activity, trauma or abnormal walking patterns (79).

In the aging foot, skin changes occur in peripheral vascular, peripheral sensory and musculoskeletal system leading to dry skin and loss of elasticity; foot dorsum and lateral subcutaneous tissue become thinner; plantar fat pads become smaller and degenerate; foot nails become thicker and more fragile and fungus infection tendency increases; vascular disorder complications occur due to circulation problems. Structural and functional changes in aging with receptors causing decreased tactile sensation, deep sensations (such as vibration and proprioception). These changes are more common in lower extremities than upper extremities (80). Especially on uneven surfaces proprioception from the foot

and ankle to maintain balance plays an important role, sensory input decreases with age. Hence, age is an important risk factor for balance and falls (81). Musculoskeletal system changes very important functional mobility that affect the bone structure, joints, tendons, ligaments and muscles (79,81).

2.3.1. Changes in Bone

There are two tissues generated by bone cells which are cortical bone and trabecular bone. While the cortical bone is the outer part with long bone matrix tubes (osteons), the trabecular bone is in the middle with an irregular bone matrix. 90% of the skeleton consists of cortical bone which is mainly in long bones. Remodeling of cortical and trabecular bones are on-going as osteoblasts for forming bones and osteoclasts for resorbing bones are connected. Thus, bone has the ability to respond when there is any change in mechanical and metabolic needs (82). Bone physiology and biochemistry changes due to ageing has a complex and partially understood structure. Yet, there are assumptions about the fact that bone marrow structure and functions are mainly affected from old age and this effect lead to osteoblasts and osteoclasts. As the structure and function changes, osteoblastic activity tends to decrease. Accordingly, bone formation and bone resorption do not occur on the same rate (83). As a result of this process, bone mass tends to change by increase bone density in adolescence, constant density in 30s and 50s and decrease as an individual age (84). Bone loss caused by aging in men is about 5% decrease in every decade (85). However, bone loss is faster in women with 10% per decade especially after menopause (86). When an individual reaches 75 years old, the bone loss ratio is around 3% in every ten years (87). The high number of microfractures on cortical and cancellous bones in old people might be linked with decreased bone density (82).

2.3.2. Changes in Joints

Lower limb joint has different alignment and morphology due to joint function yet their structure is the same at the basis. Joints are coated by a thin articular cartilage layer. Joint cavity which is the gap between the bones consists of synovial membrane secreting a fluid for bone movement. Joint capsule consisting of collagen fibrils the synovial membrane. The joints are connected with collagen fibril ligaments. Studies investigating the joints in

the ageing process often consider cartilage as cartilage plays a role on osteoarthritis. Cartilage contains chondrocytes cells in collagens, proteoglycans, matrix proteins and water and cartilage acts as a connective tissue with high density. The matrix of the cartilage enables this structure to be durable against forces such as compression, tensile and shear when the joints are moving. Cartilage might be degraded due to ageing as well as malnutrition, mechanical properties of the joint and physical activity. Additionally, detecting the difference between osteoarthritis-related degrading and aging-related degrading might be challenging. Chondroitin sulphate and oligosaccharides decreased and keratan sulphate increases at the molecular level (88). As individuals age, the width of collagen fibril and cross-link increase. Additionally, the content of water tends to decrease (89). However, ageing does not cause any change in articular cartilage thickness as well as the content of the cell (90). People with higher age might have more congruent joint surfaces compared to people with lower age. Studies explained this by expressing that incongruence at a low level might be normal in a healthy joint for synovial fluid to flow in cartilage and controlled loading. Ageing might have impacted this mechanism with protective features and joints might be constantly subjected to load (90). Additionally, ageing increases synovial membrane stiffening and synovial fluid production ability. As chondroitin sulphate decreases this might lead to decreases viscosity. Furthermore, joint capsules and ligaments might get shorter and stiffer due to collagen cross-linking. These changes cause to decrease range of motion of the lower limb joints in older individuals. Ankle dorsiflexion-plantar flexion, subtalar joint inversion-eversion was found that 12-30% less in elderly individuals in many studies (91). In a prospective study; reduced dorsiflexion angle was reported to be risk of falling. (92).

2.3.3. Changes in Tendon and Ligaments

The main duty of the tendons is to transfer the power in the muscle to the musculoskeletal system. The main duty of the ligaments is to make sure bones move coherently to prevent excessive mobility on the joint. Although their functions are different, tendon and ligaments are similar in structural terms and both of them consist of collagen fibrils. With ageing collagen fibril concentration and diameter and distance and cross-connection between collagen molecules increase. In functional terms, increasing

age might lead to decreased tendon and ligament strength and elasticity and pes planus deformity on foot structure (91).

2.3.4. Changes in Muscle

Muscle fiber types are divided into three: type I, type IIA and type IIB. Type I muscle fibers are resistant against tiredness, have high oxidative activity and capillary density and contracts slowly. Type IIA muscle fibers are less resistant against tiredness compared to type I, have medium level oxidative and glycolytic activity and contract fast. Type IIA muscle fibers are between type I and type IIB muscle fibers in terms of cellular properties. Type IIB muscle fibers get tired easily, have high glycolytic enzyme activity, low capillary density and contract fast. With ageing, the number of muscle fibers and volume decreases significantly. (8,93).

The greatest change in the muscle with ageing is decreased in total muscle mass due to decrease in the number of muscle fiber, volume and muscle cross-sectional area. Muscle mass is replaced by fat and connective tissue. Between 20-60 years old, there is approximately 40% decrease in the cross-sectional area of the muscle. From 25 years old to 50 years old, skeleton muscle mass decreases by 4% in every decade; after 50 years old, skeleton muscle mass decreases by 10% in every decade. In addition to muscle power decrease with aging atrophy, 24-37% power loss is observed in muscles (muscles for foot ankle dorsiflexion, plantar flexion, eversion and inversion) responsible from foot and ankle mobility (93,94).

In various studies, have been shown to have 24-40% loss of muscle strength in elderly individuals (95). Loss of strength in plantar flexors cause to decrease in functional mobility and balance (96). The volume of intrinsic muscles is reduced with hallux valgus in the elderly individuals (96). Aging muscle structure affects functional mobility thus, decreased muscle strength in the lower extremities is related to balance, walking speed and functional performance of the elderly individuals. Weakness in these muscles leads to falling and functional loss (95,96).

2.4. Foot-Ankle Impairments After Stroke

In individuals who experience stroke, half of them reported that they experience problems with foot (97). Studies on old-aged individuals who experience stroke showed that these individuals face with several neurological impairments. A survey conducted on 145 stroke patients showed that 17 of these individuals reported foot problems 45 months after the stroke (98). These individuals reported decreased or weaker foot/ankle movement, decreased sensing and ankle/foot pain as the top three problems. Moreover, other problems reported by the stroke patients after the stroke included foot deformity changes in plantar tactile sensing, decrease in ankle proprioception, change in motor control, decrease in hallux movement range, toe clawing, and hitch-hikers toe (99,100). For foot, ankle and lower limbs, the relationship between the foot or ankle impairment and function are unknown especially when the cause is older age.

According to Forghany et al, 30% of stroke-patient participants had age-predicted hemi-foot postural abnormalities instead of weakness or spasticity (9,101). Stroke patients with older age and weaker properties tend to have decreased walking in house environment (102,103). Ng & Hui-Chan worked on 62 chronic stroke patients 5.2 years after the stroke with standard deviation of 3.7 years who had spastic hemiplegia to uncover how ankle plantar flexor spasticity and dorsiflexor weakness related. The results of the study showed that there was significantly high relationship between the ankle dorsiflexor strength and endurance in walking. However, there was no significant relationship with plantar flexor spasticity (104,105). Based on the findings of this study, it was seen that gait efficiency was mainly linked with ankle dorsiflexors. On the other hand, the relationship between spasticity and weakness was not expressed clearly (105,106).

Spastic ankle plantar flexors might struggle to achieve desired control and force levels to help with propulsion when stance position is ending during ankle plantarflexion (107,108). On contrary, mid-stance and swing phase might have this as an active restraining agent. Thus, the weakness in the ankle dorsiflexion weakness may partially be caused by spastic plantar flexors (109,110). Dorsiflexor weakness, plantar flexor spasticity, plantar flexor passive stiffness and abnormal and higher muscle co-activation might be the caused by improper ankle dorsiflexion at gait stage in patients with impairments caused by stroke (111,112). The above-mentioned studies adopting

quantitative methods provide information about foot and ankle impairments and how these impairments effect the function and mobility after having a stroke(113,114).

2.4.1. Hemiplegic Foot and Ankle

The foot and ankle contain different joints segments, crossing muscles, sensory receptors and mechanisms forming a complex unit; this complex unit has an important role to regulate the relationship between the body and ground (115,116). The mobility is impacted from foot and ankle changes after stroke such as loss in sensorial, weakness and other changes (117,118). There are few studies investigating the effects of ankle and foot. Majority of lower limb motor impairment studies evaluate the hip, ankle and knee. Foot is not considered in these studies. On the other hand, sensory loss studies often disregard the lower limb and consider the upper limb (119,120).

2.4.2. Hemiplegic Gait

After having a stroke, lesion size, lesion location and age might impact gait abnormalities (119,121). Yet, hemiplegic gait can be defined by examining certain features. These features include decreased walking speed, asymmetrical stepping length, weight shifting decreased towards affected side and impeded balance reactions (120).

Lower limb that is involved in the process has kinematic and kinetics which are expressed with clarity (121,122). Accordingly, the steps of the affected limb is shorter and the body weight on this side is lower than contralateral one (123,124). The knee excursion decreases when standing which is called stiff knee gait and there is drop foot defined as swing phase ankle dorsiflexion decrease (125,126). Proximal joint as well as non-paretic side and trunk movements can be used for counterbalancing impairment caused problems at walking stage (127,128). This counterbalancing includes using more segments to achieve larger moves. As a result, individuals who have stroke might need for energy as there are limitations in a harmony, progression smoothness and effectiveness of the movements (129,130). The studies have expressed that synergetic, compensatory movements problems can be overcome and better limb function can be achieved when the rehabilitation practices focus on the affected joints (131,132). There is comprehensive data obtained from lower limb. Yet, this data is limited to hip, ankle and knee. The data

related to foot and stroke are highly limited. Proximal joints and foot functions are connected in terms of kinematic chain process and the gait cycle might be influenced from this function. In this sense, foot impairments and roles might be important for stroke patients (133,134).

2.4.3. Foot and Ankle Motor Impairments After Stroke

Motor impairment with the highest neurologic diagnosis in stroke cases might be the main indicator of stroke (135,136). The main impairment is movement limitation caused by the weakness on one side (137,138).

The stroke rehabilitation targets to eliminate the movement restrictions. Majority of the stroke rehabilitation studies focused on motor impairments (139,140).

There might be different impairments caused by the strokes such as muscle activity problems which are referred as motor impairments (140,141), sensory deficits, problems related to communicating (142), cognitive problems, and emotional problems (143). In this sense, stroke can have different affects including physical, mental and emotional well-being.

Stroke related physical problems can be listed as weakness, pneumonia, pressure sore, incontinence, hypertension, apraxia, mobility problems, ADL problems, aphasia, dysphasia, vision problems and pain (143). Lesion size and lesion location can change the stroke-related symptoms (144). While some of these problems are experienced throughout life, other might be temporary. In some of the patients, the symptoms might get better in the first three months due to edema relief, toxin elimination and better lesion area circulation (145). A longer-term recovery mechanism is based on how the central nervous system copes with the lesion. This coping from cortex to muscle in the neuromuscular system might include restitution, reorganization or compensation (146). There are ambiguous evidence on post-stroke motor performance. There are different terms and levels for describing the motor ability and its results (147). International Classification of Functioning Disability and Health (ICF) framework is adopted as the classification code where foot and ankle-related motor impairments are considered under this context (as shown in Figure 2-3). After providing a general description about the post-stroke motor deficit problems (pathological changes, level I), lower leg structural and functional changes are given (impairments, level II). Afterwards, how the foot and ankle

problems cause mobility issues in ADL (activity limitations, level III) and social aspects (participation restrictions, level IV) are presented.

ICF Classification	Level of Analysis	Motor Impairments (In foot-ankle after stroke)
Health Condition	I.Primary Pathology	Upper Motor Neuron Lesions
↕		↕
Body Function/Structure	II. System Function	Foot -Ankle Function/Structure
↕		↕
Activity	III.Individual Performance	Balance and Gait
↕		↕
Participation	IV. Society Involvement	Community Ambulation

Figure 2. 3. Inter-relationship between foot-ankle problems and mobility to ICF

2.4.3.1. Upper Motor Neuron Lesions

Upper Motor Neuron (UMN) syndrome is the main area for describing motor symptoms after a stroke (148). The traditional classification involves positive and negative properties where positive ones are spasticity or hyperreflexia as exaggerates muscle reaction and negative features are muscle force control or generation problems (149).

A new classification (150) expressed that UMN lesions have primary and secondary features. Primary features involve muscle weakness, motor control problems and spasticity. Secondary features involve changes in the connective tissue and changes in the motor patterns. Ineffective treatment of the primary features might result in mechanical and functional changes and these changes are classified as secondary features. The affected side might have different properties after a stroke. Yet, mobility problems

are mainly caused by muscle weakness, decreased motor control and secondary muscle and soft tissue changes (150).

2.4.3.1.A. Muscle Weakness

Voluntary motor drive decrease and motor unit recruitment pattern problems lead to post-stroke muscle weakness (12,151). Later, this is increased as the muscle disuse leads to changes. Muscle weakness can be observed commonly and this weakness might predict post-stroke decreased motor recovery and performance. Gait function and lower limb muscle function has a negative relationship. This also significantly effects ADL and post-stroke life quality (152). Compared to proximal joints, ankle joint is reported to have higher weakness in the affected leg. These reports are adopted in rehabilitation practices in terms of Neurodevelopmental treatment or Bobath approach). In the treatment process, proximal joints as the main drivers of the motor recovery in distal segments for stabilizers and synergists of distal motions should be the main focus (153).

2.4.3.1.B. Lack of Motor Control

Stroke interrupts detailed, fast, and skilful movement coordination. UMN syndrome which is the interrupted information flow between cerebral and spinal centers is considered to the negative feature of the abnormal muscle activity pattern. The synchronized motor unit recruitment patterns are interrupted at a level where the movement happens with abnormal contraction pattern. Accordingly, this leads to temporal parameters deviation and motor unit excitement including longer activity time, changes in timing and abnormal co-activation pattern (153,154). Abnormal muscle activation timing is common in the foot and ankle complex. In this timing, calf muscles are activated early in terminal and the swing pushes the foot and ankle into plantar flexion and inversion. Thus, the entire foot contacts the ground where only the heel should contact (154). There are cases with abnormal co-activation. Lower post-stroke co-activation between gastrocnemius and tibialis anterior muscles was observed; this might lead to single leg posture imbalance (155) and weight transfer limitations during gait (156).

2.4.3.1.C. Spasticity

The general definition of spasticity as a motor disorder is increasing velocity in tonic stretch as tendon jerk is increased due to stretch reflex hyperexcitability; it is one of

the UMN Syndrome positive property. Muscle stretch reflex controlling inhibitory mechanisms decreased after a brain damage and this leads to hyper-activity. Motor impairments, gait deviations and secondary complications including joint stiffness and muscle contracture were believed to be caused by spasticity. “Spastic gait” term was commonly used for hemiplegic gait deviation in the past (157). The electromyography (EMG) records in hemiplegic “drop foot” people indicated that there was no difference between paretic and non-paretic gastrocnemius activity. These results indicated that ankle joint deformity was linked with anterior muscle activity. Due to problems with modulated firing signals, anterior muscle struggles to sustain constant force during activity phase. UMN lesion showed that passive movements resistance often called as spasticity was linked with muscle tissue mechanical feature changes (157,158). Accordingly, moments fail to surpass the resistive forces due to passive mechanisms instead of reflexes (159). Spasticity properties were reported to be at muscle shortening and joint stiffness areas with high risk including ankle joints and calf muscles in the lower limb (160).

The relationship between spasticity and motor performance arise more doubt as function limitation was not mainly contributed by spasticity. Accordingly, post-stroke impairment being related to spasticity is accepted at a lower level. Modified Ashworth Scale is common in the assessment of spasticity. Reliability and validity of this scale are shown in the literature (31).

Modified Ashworth Scale

0: No tonus increase.

1: Slight muscle tonus increase, minimal resistance at the end of the movement when the extremity is moved in flexion or extraction direction.

1+: Slight muscle tonus increase, resistance occurs in the middle of last half of the motion area but extremity is moved easily.

2: More visible muscle tonus increase, resistance occurs in the majority of motion area but the movement is completed.

3: Significant muscle tonus increase, passive movement is challenging.

4: Affected extremity was rigid during flexion or extension.

2.4.3.2. Impairments of Foot and Ankle Structure After Stroke

Instead of being a single rigid system, post-stroke foot and ankle structure and function is evaluated as multiple segment system (161). The unit consist of three sections in terms of functions which are the hindfoot with shank bones distal ends (tibia and fibula), talus and calcareous; the midfoot, with cuboid, navicular, and three coniform bones; the forefoot with metatarsals and phalanges (Figure 2.4.). It is better to understand all of these structures to better evaluate the factors affecting foot and ankle performance.

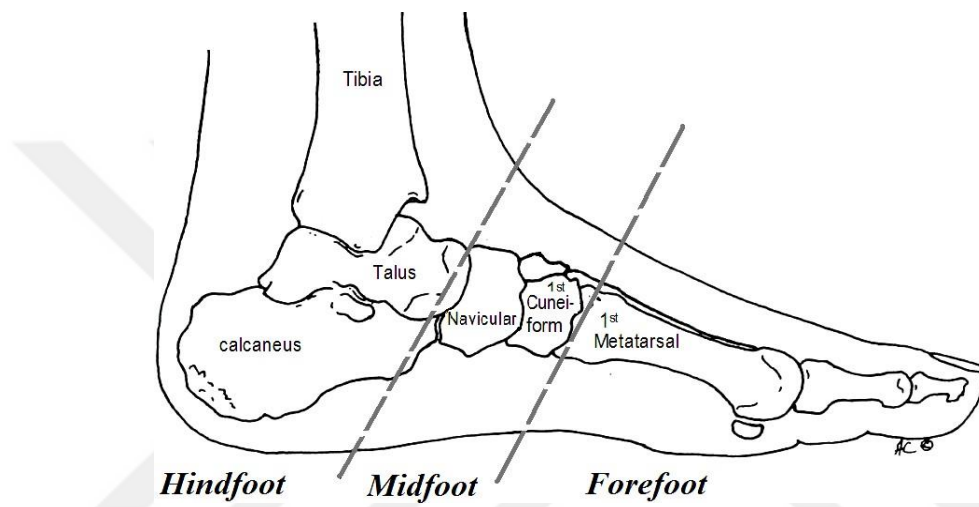


Figure 2. 4. The bone structure and regions of foot and ankle complex (161)

There are two joints in the hindfoot contains which are “talocrural joint” providing articulation between shank bones and talus, and the “subtalar joint” (STJ) between the talus and calcaneus. Talocrural motion is often used for regulating dorsiflexion and plantar flexion. On the other hand, STJ regulates calcaneal eversion and inversion. “Midfoot joint” or “transverse tarsal joint” as the main articulation consists of the talonavicular and calcaneocuboid joints. The midfoot is responsible from complex movements and linked with subtalar joint (162)

2.4.3.3. The Role of Foot andAnkle Complex in Balance and Gait After Stroke

After the stroke, people struggle to stand up and walk with stability. An individual should have standing balance, motor control, mechanical energy generation and proper movement for secure and independent locomotion (163).

Post-stroke problems experiences by the individuals are as follows:

2.4.3.3.A. Upright Balance

Standing balance means keeping the body mass center (COM) stable for base of support (BOS) (164). When standing upright, the balance ability is divided into three as static balance with preserving balance in standing position; body segments movement by keeping BOS stable; and dynamic balance by changing BOS and COM repositioning for new BOS. Individuals need to achieve the old BOS to new BOS transition by keeping postural stability to avoid falling in normal activities such as reaching, moving or carrying something. On the other hand, dynamic balance is required for actions such as stepping. Safe walking must involve all three components (165).

Postural sway measurement is frequently used for assessing the balance at standing position. Yet, there is low correlation between postural sway and the number of falling incidents. This means, post-stroke balance problems cannot be completely explained by postural sway. While there is ambiguous correlation between sway and balance function, there has been studies that show significant postural sway difference for patients control groups. In these studies, postural sway of the stroke patients was higher than the control group (165,166). Higher postural sway might not indicate balance problems (166). Yet, failure of the motor control system to adjust might lead to falling.

2.4.3.3.B. Motor Control

Balance ability starts to develop in the childhood and it is a complicated procedure that requires both learning and practice (167). The CNS is the main actor to keep body steady by assuming instabilities and triggering muscle forces (Horak et al., 1997). Ankle, hip and stepping strategy are the main strategies to preserve the balance (168). With these strategies, body can preserve a stable position on the feet. Lower leg and knee muscles often start the ankle strategy. Here, the COM is moved in anterior or posterior direction. In terms of hip strategy, hip and trunk muscles start it and hip abductors and ankle muscle co-activation are needed for taking a step (169). Small perturbations are encountered by the ankle while faster and larger COM displacements are accommodated by the hip strategy. Both hip and ankle strategies are required in balancing to help COM to have a base of support. Stepping strategy that causes BOS to change when a stepping to any direction is the widest displacement. Ankle and hip strategies act independently from

stepping strategy. The stepping strategy is often applied to dynamic tasks and locomotion (169).

Stroke might cause delayed paretic leg muscle reaction (170). Accordingly, the muscle activity might have lower level of coordination. Together with weakness, ankle sway range decreases and this might lead to smaller BOS diameters. Ankle strategy's effectiveness decreases with smaller BOS for fast reaction cases. In this sense, post-stroke patients tend to use hip strategy (171).

Affected side compensatory muscle might experience problems and normal side muscles try to make up for these muscles. BOS is shifted to unaffected side due to the asymmetrical load. Therefore, hip strategy usage is limited and stroke patients might use stepping strategy earlier due to impairment in other strategies (172).

Peripheral inputs, attention, motor performance, experience and intention shape the postural responses (173). Muscle performance plays a vital role in postural control as frequently expressed in the related literature. There is a close relationship between muscle weakness and balance problems (173,174). Sensorimotor impairments including proprioception and verticality perception which are evaluated in fewer studies can be linked with post-stroke balance problems (175).

2.4.3.3.C. Mechanical Energy Production

Stroke significantly decreases walking speeds of the patients while there are different gait abnormalities. Decreased walking speed is one of the most common post-stroke gait function measurement. Propulsive force at push-off and this is related. Hip extension and ankle plantar flexion angles are decreased during push-off in stroke patients. Furthermore, weakness causes plantar flexors EMG activity to be decreased. Accordingly, the push-off power decreased and mechanical energy production decreases as well. This weakness in the push off might continue in the swing phase if decreased knee flexion and push-off problems are related (176).

2.4.3.3.D. Ankle and Foot Movement

The post-stroke UMN lesions might lead to inadequate dorsiflexion at swing phase and abnormal foot contact in early stance (177). Lack of tibialis anterior activity leads to swing-phase dorsiflexion decrease. Therefore, it is not possible to do a heel strike

and the toes or the entire foot tend to contact with the ground referred as “drop-foot” (178). This ankle dorsiflexion deficiency is balanced with knee and hip flexion increase. Furthermore, lower limb circumduction generate adaptation for this deficiency and to prevent the toes catching at limb swing phase. At the same time, tow dragging in this phase might be forestalled with lateral pelvic tilt or trunk bending (179). Larger COM stroll in frontal plan is included in proximal compensation strategies. Since body weight stroll to frontal plane predicts the fall incident, this recompense might have negative effects (180).

2.4.3.4. The Role of Foot and Ankle Complex in Post-Stroke Community Ambulation

Walking in the community without any problem is the hard-reached challenge of the rehabilitation after stroke (181). To move independently and participate in social life, high motor performance level is necessary. While there are rehabilitation programs in the community, majority of these practices are at clinical setting. Moreover, studies often conducted clinically or in gait laboratories. These setting provide more advanced measurement options compared to self-reports in the community settings. Walking speed is signified as the most important post-stroke recovery indicator. (182). Environmental effect on hemiplegic gait and balance are unknown. Additionally, there is limited knowledge about how stroke patients can adapt to outdoor environments (183). It is important to use standardizes environment tests to understand how stroke patients adapt to communities.

Gait propulsive power generated by foot and ankle are indicated at laboratory settings which revealed a strong relationship between lower limb motor performance and walking speed after stroke (184). There are few data on how ankle and foot influence walking in community setting (ambulation).

2.4.4. Foot and Ankle Sensory Impairments After Stroke

2.4.4.1. Foot Sensation, Gait and Balance

Peripheral feedback should be provided to the CNS for muscle activities and body segment positioning (185). Visual, vestibular, and somatosensory systems are responsible for these feedbacks to CNS where the data is processed (186). In this process, CNS evaluates the sensory inputs and to obtain feedback for different conditions, one input is

favour over the others (187). When the environment has good lighting and when the healthy individuals are on a firm ground, somatosensory sources are mainly used (185,188). When standing in the upright position, the foot has direct contact with the ground and it is the only segment with direct contact and sensation from foot has a vital role for somatosensory inputs to sustain balance at standing position (189).

When individuals get older, the foot sensory perception decreases. Such decrease requires studies to investigate how there are foot sensory changes with age to better understand the foot contributes to mobility. Compared to younger adults, older adults have fewer sensitive feet to stimulation received mechanically (190). There are high number of studies analyzing the relationship of foot sensation decreases on postural stability in older people (8,191). The results indicated that foot sensation and postural stability and balance control is related and related to different problems in older people. Aging related neuromuscular system morphologic and functional properties should be considered for postural instability in older people. Aging leads to decreased CNS activity for peripheral input processing (192). Furthermore, the muscle performance decreases and these factors might increase the balance problems (193). In older people, physical performance might be limited due to decreases in cognitive, sensory, and motor functions. In this sense, the factors causing the balance problems are multi-faceted. Studies investigated the postural sway changes by changing foot sensation in healthy individuals to understand the effect of foot sensation on balance as a single criterion. Foot sensation was decreased by temporary local ischemia using a tight cuff to wrap around the leg or using ice to cool down the feet and standing on foam block or similar surfaces (194). Studies showed that as the sensation decreased, postural sway increased and therefore, foot and ankle play an important role for balance and postural control. Yet, since there are different factors contributing to balance such as sensory systems, sensory loss alone is not sufficiency to explain balance problems. If there are problems with sensory input sources, CNS has the ability to replace and compensate this with other inputs (195). When there are few or limited somatosensory inputs, visual and vestibular feedbacks might be preferred. In case of disturbed or few vestibular or visual sensory inputs such as darkness, the postural control system tends to rely on the data coming from the foot sensory system. Under challenging situation such as trying to balance on one leg or closing eyes while standing, foot tactile sensation has more dominant role (196).

When the data flowing from the feet decreased, the lower limb muscle patterns are affected (197). Such changes also affect plantar pressure as well as lower limb kinematics (198). In this sense, the entire gait cycle and walking pattern might be impacted.

2.4.4.2. Sensory Impairment After Stroke

After having a stroke, there are high number of cases with reported sensory impairment (199). Studies showed that post-stroke sensory impairment can be seen in the half of the survivors. Accordingly, sensory impairment is considered as a significant long-term recovery prognostic sign where motor recovery is slower in these patients, patients have longer hospitalization and experience lower balance (200). On the other hand, there is insufficiency understanding between sensory deficit and functional abilities while sensory assessment is common in post-stroke identification at clinical setting. There is a high relationship between sensory and muscle weakness and stroke severity. Yet, the level of sensory impairment and motor impairments correlate to how serious the stroke is and it is not possible to understand how each of these factors contribute. On the other hand, balance problem is independently predicted by the weakness in muscle (200). Thus, muscle weakness can have an impact on function and mobility. There are still questions about the relationship between sensory impairments and balance and mobility problems.

2.4.4.3. Foot and Ankle Sensory Impairments in People with Stroke

Hemiparetic upper limb is the most commonly investigated topic in sensory impairment after stroke (196,200). Yet, studies related to the foot and ankle are limited in number. There are more studies in ankle proprioception compared to tactile component in the hemiplegic foot and ankle complex. Ankle proprioception plays an important role on balance in general and on walking performance. Furthermore, hemiplegic foot loading while walking might be affected since people tend to be intimidated by placing the body weight sufficiently on a leg which they have low awareness. The peak pressure of the stroke affected leg in stroke patients is lower feet. Yet, the contribution of the lower pressure on weight acceptance or whether there is a relationship with motor deficiency alone is not clear. A study showed that foot tactile sensory impairment is more than proprioception. In this study, 67 out of 102 in people with stroke (66%) reported tactile problem while 28 subjects (27%) reported proprioceptive impairment (200). There are

limited studies on foot sensory problems in the related literature. Yet, a study conducted recently showed that foot sensory problems might be more common than the current data (200).

2.5. Balance After Stroke

Stroke has effects on the postural control in addition to mobility and brain sensorimotor lesions. Postural control is linked with mobility issues (200). While stroke patients might have problems with standing up, some of the patients might experience asymmetric limb and weight bearing and signal delays when they are finding balance. The posture when standing upright might lead to using different balance strategies. Thus, non-paretic side and trunk might experience high level of reaction; this might further cause unsecure support for the body mass and increase the falling risk. The definition of balance is given as controlling the mass of the body based on a support. Balance is important for moving safely and avoiding falls. Having a stroke might impair the postural control with sensory and motor impairments. In this sense, in stroke patients, it is important to ensure balance recovery in the entire rehabilitation process for mobility, being independent in ADLs and to be involved in social life (201).

2.5.1. Falls

Falls as one of the most frequently encountered complications after a stroke has a ratio of 10.5-46% in different units. In incentive care centers, falling occurs at 14% where this ratio is 24% for the rehabilitation unit and 39% for a geriatric rehabilitation unit. In rehabilitation centers, calculated falling incidents for 100 patients is 15.9 (201). In addition to high prevalence among patients with stroke, falling as an important complication due to certain consequences leads to falling anxiety and limits the activities. This might significantly restrict the participation of the patient to the rehabilitation. Additional problems and especially bone fractures after falling hinders rehabilitation. Falling generally occurs during transfers or forward reaching from a wheelchair. Falling and consequent falling anxiety might lead to the social isolation of the patient.

2.5.2. Risk Factors for Falls

To prevent falling which is extremely important due to its consequences, it is important to define risk factors and take necessary precautions. Various studies analyzing

the risk factors have identified numerous risk factors with variable degrees. It is believed that identifying and eliminating these factors can significantly lower falling frequency (202, 203).

Age: Falling frequency tends to increase in patients above 75 years old (202,204). Uğur et al. (209) found that the average age of patients with stroke who falling at least once was 62.5 and patients with stroke and without falling history were determined as 59.

Depression: Especially, the first year after the stroke is considered as the most important risk factor. Secondary depression might affect this. In the first years after the stroke, the depression rate is 30-50%. Studies found a significant positive relationship between falling and depression. Increased depression intensity tends to increase falling incidents (204).

Heart disease: Studies investigating the relationship between falling and hearth disease in patients with stroke revealed similar results. For example, while it is reported that falling risk is increased during the increasing period for pneumonia and chronic diseases such as heart disease that are suggested to have a positive relationship (204), studies suggesting to have a negative relationship argues that decreased functional capacity in the heart disease is responsible (202).

Right hemisphere infarct: When the relationship between hemispheric localisation and falling was considered, it was seen that right hemisphere lesions caused falling more. It is believed that proprioception disorder, negligence and lack of attention might contribute to this situation (202).

Mental dysfunction: It is believed that insufficient perception might be connected to a lack of attention (205).

Urinary incontinence: It is believed that it might be connected with brain damage intensity or low brain functionality level (205).

Male gender: The reason for gender to be a risk factor is unknown.

Sedative and hypnotic medications: Medications used by the patients with stroke is known to cause balance disorders and increase falling risk.

Visual disorders: Correcting visual disorders is vital to decrease the falling caused by insufficient seeing.

Decreased lower extremity muscle power-functional insufficiency: It is known that individuals with higher functional insufficiency tend to fall more. Functional indicators (low daily life activity score, postural insufficiency, bilateral motor insufficiency) indicate decreased movement and trust and increased dependence. It is known that the Barthel index is lower in the group with falling (202,205).

Balance problems: Balance problems as the most important risk factor for falling might lead to falling especially during dressing (206). Majority of the falling incidents occur during walking that requires dynamic and reactive balance (207). Patients with balance problems might use wheeled walkers to help mobility and decrease the falling risk. For this purpose, patients with stroke should have balance exercise during rehabilitation (207).

2.5.3. Falls Reasons

1. Extrinsic reasons: (11%) Loss of gravitational center, stumbling during oscillation phase, slipping during stepping phase lead to extrinsic falling. Loss of gravitational center was indicated as the most frequent extrinsic falling reason.

2. Intrinsic reasons: (32%) Insufficient mobility, balance problems, cognitive disorders, loss of consciousness were indicated as intrinsic reasons. The most frequent reason is balance problems.

3. Non-bipedal position: (25.5) Falling during sitting and lying is often caused by the patients; however, there are rare incidents caused by insufficient support.

4. Unclassified reasons: (31%) Falling with unknown reason or unclassified falling are in this group (208).

3. MATERIALS AND METHODS

3.1. Research Groups

This study planned to investigate the comparison of foot and ankle characteristics of individuals with stroke and health individuals as well as individuals with stroke with and without falling history was conducted on individuals with stroke and healthy individuals without any neurologic activation in Ümraniye Gülen Çocuklar Special Education and Rehabilitation Centre. This study included 24 cases with stroke (12 with falling history and 12 without falling history) and 24 healthy individuals in similar ages. Individuals were asked questions about the frequency and circumstances of any falls in the last 12 months. Before this study, researchers appealed to Yeditepe University, Non-Invasive Clinical Research Ethical Board. The study started after receiving ethical board approval on 12/02/2020. (KAEEK:1166) (Appendix 1).

3.1.1. Study Group

Study group inclusion criteria included being an individual with stroke and above 65 years old, being level 3 or higher for FAC ambulation classification, walking at least 6m with or without walking aid device, at least 1 year after the stroke, matching World Health Organization stroke definitions and having cooperation to understand assessment commands and their mini-mental state examination (MMSE) scores were 24 points or higher .

Study group exclusion criteria included having other neurologic disorders, vestibular or inner ear disease, surgical history in the lower extremities, systemic diseases that might affect foot and ankle, lower-extremity amputation and injury in foot and ankle.

3.1.2. Control Group

Control group inclusion criteria included being a healthy individual over 65 years old without stroke and voluntary participation. The subjects in the control group were age-matched to those in the study group.

Control group exclusion criteria; participants had no neurological injury, waist pain, spondylarthritis, or rheumatoid arthritis; had not undergone orthopedic surgery; and had no pain or abnormality in the hip or knee joints.

All individuals with stroke and healthy individuals participating in this study were informed and these individuals signed “Clarified Consent Form” showing that they are volunteering to this study (Appendix-2).

3.2. Evaluation Methods

3.2.1. History

The medical history, name-surname, age, height, body weight, body mass index, time after the start of the stroke, falling history, resume, family history, stroke reason, affected side, dominant side, surgical history, used orthosis information of the all individuals participating in this study are orally received and recorded by analyzing hospital files.

3.2.2. Muscle Tonus

Muscle tonus was evaluated with the Modified Ashworth Scale (MAS). The assessment is conducted during passive movement of the affected side based on the resistance by the spastic muscle. Resistance to the passive movement was scaled between 0 and 4. In this study, measured the degree of spasticity of the ankle plantar flexors, which are known to greatly affect gait imbalance (9). MAS phenomenon was conducted for hip flexors, hamstring muscle group, quadriceps femoris, gastro-soleus and adductor muscle groups. Measurements were completed on a bed with suitable hardness and width, without placing a pillow and by keeping the heat in the middle position, with a maximum extension of lower and upper extremities and by lying backwards parallel to the body. Passive joint movements were made in 1 second as recommended by Bohannon and Smith for measurement standardization. Measurement positions were completed as expressed below.

M. Gastrocnemius: In full knee extension, physiotherapist placed the hand on ankle proximal and grabs the foot from the plantar side with the other hand and determined muscle tonus when moving the feet from maximum plantar flexion to maximum dorsiflexion.

M. Soleus: With 45° flexion position of the hip and the knee, physiotherapist placed the hand on ankle proximal and grabs the foot from the plantar side with the other

hand and determined muscle tonus when moving the feet from maximum plantar flexion to maximum dorsiflexion.

Knee Flexors: With 90° flexion position of the hip, physiotherapist placed one hand to the femur and the other to proximal of the ankle and determined muscle tonus when moving the knee from maximum flexion to maximum extension.

Hip Flexors: In facedown position and with 90° flexion position of the knee, physiotherapist placed one hand on the pelvis and grabs the hip with the other hand and determined muscle tonus when moving the hip to maximum extension.

M. Quadriceps: When on facedown position, physiotherapist kept one hand stable on femur distal and grabs the ankle with the other hand and determined muscle tonus when moving to maximum flexion.

Hip adductors: When physiotherapist was stabilizing proximal femur with one hand, physiotherapist placed the other hand on the ankle proximal and moves the hip from maximum adduction to maximum abduction to determine muscle tonus. The straight position of the knee was considered.

3.2.3. Functional Ambulation Classification (FAC)

This scale assesses the ambulation skills of the patients. The scale is divided into six categories scored between 0 and 5. FAC 0: No ambulation, FAC 1-2: no walking without the support of one person, FAC 3-5: walk on his/her own for 6 meters. FAC Stage 0: Non-functional ambulation, Stage 2: Episodic help-dependent ambulation, Stage 3: Supervision-dependent ambulation, Stage 4: Independent ambulation on a level surface, Stage 5: independent ambulation on stairs and slope.

3.2.4. Evaluation of Foot and Ankle

Foot Posture Index

Foot posture was assessed by Foot Posture Index. During the assessment, cases were asked to stand still and in a relaxed position. The test consisted of a total of 6 items with 3 anterior foot assessments and 3 posterior foot assessments. This application that lasted approximately for 4-5 minutes was conducted with posterior, medial, lateral and anterior observation and bilaterally based on palpation.

Posterior foot assessment parameters were as follows:

Talus head palpation was marked by palpating talus head in anterior from the medial and lateral and higher or equal sensation of the talus head on either side was scored and recorded. This was scored by the posterior look to the slope above and below lateral malleolus. Frontal surface position, pronation or supination of the calcaneus was determined by observing foot long axis line from the posterior direction. This line which should be vertical under normal conditions was scored with negative values for 5° and higher inversion (-2, -1) and scored with positive values for 5° and higher eversion (2, 1).

Anterior foot assessment parameters were as follows:

Aneurysm in the talonavicular joint region, medial longitudinal arc structure and abduction/adduction of the anterior foot compared to posterior foot were assessed and these criteria were scored between -2 and +2. Total scores were recorded interpreted as 0 being foot neutral position, positive values as pronation and negative values as supination. Values between 0-5 were recorded as normal, 6-9 were pronation, 9-12 were extreme pronation, -6/-9 were supination and -9/-12 were extreme supination.

Navicular Height

In navicular height measurement, cases were asked to stand still in a relaxed position. The medial bulge of navicular tuberosity was palpated, the distance to the marked location was measured with a measuring tape and recorded in centimeters.

Navicular Drop Test

In the Navicular Drop Test, the medial bulge of the tuberosity was determined with palpation and marked with a pen. In the cases, navicular tubercle is marked on a paper while sitting on a chair with 90° hip and knee position and when feet are on the ground and patients were asked to stand up. After standing up, navicular tubercle was again marked on the same paper and the difference between two marks are measured and recorded in centimeters. To minimize the error margin during palpation, each measurement was repeated 3 times and the average score was recorded.



Figure 3. 1. Navicular Drop Test

Resting Calcaneal Stance Position Angle Measurement

The RCSP angle measurement was performed as follows:

The patient is aligned to lie in the prone position on the examination table.

- The ankle is dorsiflexed to 90°, so that the plantar surface of the heel is perpendicular to the leg in the sagittal plane.
- The subtalar joint is not rotated in varus or in valgus attitude. The posterior aspect of the calcaneus is bisected with a fine marking pen.

The patient then takes standing position on the platform

- The patient marches in place at least 5 times on each foot until achievement of a comfortable angle and base of stance.
- The movable arm is aligned on the calcaneal bisection line. The stationary arm is aligned parallel to the supporting surface.
- RCSP is the angle formed by the bisection of the posterior aspect of the calcaneus to the supporting surface during relaxed standing (14).



Figure 3. 2. Method of positioning and clinical determination of RCSP

Sensation of Plantar Aspect First Metatarsophalangeal Joints (MPJ)

10g retractable monofilament was adopted to evaluate 1st MPJ plantar sensation as recommended by the American Diabetes Association. The monofilament is constructed to buckle or bend when 10 g of force is applied to the plantar surface of the foot, as seen in Figure 3.3. Next, examine the foot by first asking the patient to close his or her eyes and to indicate “yes” or “no” when asked whether the monofilament is being applied at a particular site trying to avoid areas of callus to ensure accurate perception of pressure.



Figure 3. 3. 10g Monofilament Test

Ankle and 1st MPJ ROM

Universal goniometer is selected for active ankle dorsiflexion ROM measurements. During measurements participants put their knee on a stool to rest with anatomical and marks (22). Furthermore, Hopson methods for non-weight bearing position is adopted for active 1st MPJ extension ROM measurement (25). There will be three ROM measures and after these three measurements, the mean of three measurements will be computed.



Figure 3. 4. Ankle Dorsiflexion ROM

Paper Grip Test (PGT)

The Paper Grip test to perform, the patient is seated with their hip, knee and ankle at 90° and is instructed to use their toe muscles to push down on a piece of cardboard while the clinician stabilizes the ankle and forefoot and attempts to slide the cardboard away from the toes. The test is performed three times for the hallux and lesser toes individually and is documented as a pass if the patient can hold the cardboard for all three trials, and a fail if they fail to grip the cardboard on at least one trial.



Figure 3. 5. Paper Grip Test

Foot Function Index (FFI)

The FFI (questionnaire)(Appendix-3) consists of 23 self-reported items divided into 3 subcategories on the basis of patient values: pain, disability and activity limitation. The patient has to score each question on a scale from 0 (no pain or difficulty) to 10 (worst pain imaginable or so difficult it requires help), that best describes their foot over the past week.

The pain subcategory consists of 9 items and measures foot pain in different situations, such as walking barefoot versus walking with shoes.

The disability subcategory consists of 9 items and measures difficulty performing various functional activities because of foot problems, such as difficulty climbing stairs.

The activity limitation subcategory consists of 5 items and measures limitations in activities because of foot problems, such as staying in bed all day. Recorded on a visual analogue scale (VAS), scores range from 0 to 100 mm, with higher scores indicating worse pain. Both total and subcategory scores are calculated.

Manchester Scale

To determine the hallux valgus deformity level in the individuals, “The Manchester Scale” was applied. In this scale, hallux valgus deformity level was considered in 4 levels as none (1), slight (2), moderate (3) and intensive (4) and this scale is used a clinical tool with the foot photographs.

3.3. Data Analysis

Data analysis was conducted with SPSS 21.0 package program. Results did not satisfy the assumption of normality; thus, non-parametric analyses were completed. The data for foot and ankle characteristics for the affected and non-affected sides of the study group were compared using Wilcoxon Signed Ranks. Affected sides of the study group and non-dominant sides control group and non-affected sides of the study group and dominant sides control group and stroke fallers and stroke non fallers were compared using Mann Whitney U test. Fisher Exact Test analysis was used to detect differences for the dichotomous variable. To examine the correlation between the results for the foot posture, Spearman's correlation analysis was conducted. The significance level was set at $p < 0.05$.



4. RESULTS

This study included a total of 48 individuals with 24 stroke patient and 24 individuals in the control group without stroke.

The study group average age was 68 ± 6.94 . The average weight was 70.5 ± 7.42 kg and height was 1.63 ± 8 cm. The average age was 69 ± 5.82 . The control group average weight was 70.5 ± 7.42 kg, height was $170 \pm 10,8$ cm and BMI was $28,80 \pm 5,1$ kg/m². General characteristics of the study and control group are summarized in Table 4.1.

Table 4. 1. Study and control group physical characteristics

	Study Group	Control Group	p
Age	68 ± 6.94	69 ± 5.82	0.531
Height	1.63 ± 8	$1.70 \pm 10,8$	0.025
Weight	70.5 ± 7.42	78 ± 8.4	0.265
BMI	$27,29 \pm 5.62$	$28,80 \pm 5,1$	0.868

t-test

The study group included 7 male and 17 female participants. The control group included 19 male and 5 female. The mean time post stroke was 7 ± 5.06 . 7 patients had a stroke on the right-hand side and 17 had a stroke on the left-hand side (Table 4.2).

Table 4. 2. Study and control group general characteristics

	Study Group	Control Group	p
Gender (M/F)	7/17	19/5	0.039
Time post stroke	7 ± 5.06		
Fall history	12	1	0.035
Weakness Side(L/R)	17/7		

Chi-Square tests

When the Functional Ambulation Scale (FAC) scores of the study group were considered, it was seen that 7 individuals have 3, 12 individuals had 4 and 5 individuals had 5 FAC score (Table 4.3).

Table 4. 3. Number of study group participants for FAC score

FAC score	Individuals F (%)
3	7 (29)
4	12 (50)
5	5 (21)

When the Functional Ambulation Scale (FAC) scores of the control group were considered, it was seen that 10 individuals had 4 and 14 individuals had 5 FAC score (Table 4.4).

Table 4. 4. Number of control group participants for FAC score

FAC score	Individuals F (%)
4	10 (42)
5	14 (58)

When the Modified Ashworth Scale (MAS) scores, measured the degree of spasticity of the ankle plantar flexors of the case group were considered, it was seen that 11 individuals have 1, 9 individuals had +1 and 4 individuals had 2 MAS score (Table 4.5).

Table 4. 5. Number of participants for MAS score

MAS score	Individuals F (%)
1	11(46)
+1	9 (37)
2	4 (17)

When the affected and non-affected foot in the case group were compared, there was no statistically significant difference between the two groups in terms of hallux valgus existence ($p>0.05$). However, plantar sensation existence was higher in number in the affected foot ($p=0.009$) (Table 4.6).

Table 4. 6. Plantar sensation comparison in affected and non-affected foot

		Study Group	
		Affected foot F (%)	Non-affected foot F (%)
Plantar sensation aspect	yes	8 (33)	16 (67)
	no	16 (67)	8 (33)

Fisher Exact test $p=0.009$

There was no statistically significant difference between the plantar sensation of 12 individuals with fallers in the study group and 12 individuals with non-fallers in the study group ($p>0.05$)

In affected foot in the study group, plantar sensation existence was higher in number in the non-dominant foot in the control group ($p=0.000$) (Table 4.7).

Table 4. 7. Plantar sensation comparison in affected and non-dominant foot

		Study-Control Group	
		Affected foot F (%)	Non-dominant foot F (%)
Plantar sensation aspect	yes	8 (33)	21(88)
	no	16 (67)	3(12)

Fisher Exact test $p<0.001$

It was observed that the foot posture index, RCSP angle and dorsiflexion angle scores of the affected and non-affected foot of the patients in the case group showed no statistically significant difference ($p>0.05$). However, it was seen that metatarsal joint extension ($p<0.001$) score was significantly higher in the non-affected foot. Navicular drop ($p<0.001$) in the affected foot was significantly higher (Table 4.8).

Table 4. 8. Comparison of affected and non-affected foot

	Study Group						p value
	Affected foot			Non-affected foot			
	Median	Min.	Max.	Median	Min.	Max.	
Foot posture index	8,00	-4,00	12,00	7,00	-4,00	11,00	p>0,05
Dorsiflexion	10,00	6,00	18,00	12,00	6,00	20,00	p>0,05
First MPJ extension	20,00	5,00	30,00	32,50	10,00	45,00	p<0,001
Navicular drop	14,00	8,00	18,00	12,00	9,00	16,00	p<0,001
RCSP angle	12,00	8,00	20,00	11,50	7,00	18,00	p>0,05

Wilcoxon test

When the affected foot in the study group and non-dominant foot in the control group were compared, while foot posture index ($p=0.000$), navicular drop ($p=0.000$) and RCSP angle ($p=0.000$) were higher in the affected foot in the control group, ankle dorsiflexion and first metatarsal extension angle was significantly higher in the non-dominant foot in the control group ($p=0.000$) (Table 4.9).

Table 4. 9. Comparison of affected and non-dominant foot

	Study-Control Group						p value
	Affected foot			Non -dominant foot			
	Median	Min.	Max.	Median	Min.	Max.	
Foot posture index	8,00	-4,00	12,00	4,00	-2,00	6,00	p<0,001
Dorsiflexion	10,00	6,00	18,00	15,00	8,00	25,00	p<0,001
First MPJ extension	20,00	5,00	30,00	39,00	23,00	60,00	p<0,001
Navicular drop	14,00	8,00	18,00	8,00	5,00	12,00	p<0,001
RCSP angle	12,00	8,00	20,00	5,00	4,00	7,00	p<0,001

Mann Whitney U test

When the participants in the study group and control group were compared, it was seen that foot function index total score and sub-scores of the case group were statistically significantly higher ($p=0.000$) (Table 4.10).

Table 4. 10. Total foot function index score and sub-scores

	Study-Control Group						p value
	Affected foot			Non dominant foot			
	Median	Min.	Max.	Median	Min.	Max.	
FFI total score	20,00	5,00	40,00	2,00	0,00	10,00	p<0,001
FFI pain	2,00	0,00	6,00	0,00	0,00	2,00	p<0,001
FFI disability	8,00	1,00	14,00	0,00	,000	6,00	p<0,001
FFI activity	8,00	2,00	15,00	0,00	0,00	4,00	p<0,001

Mann Whitney U test

When the non-affected foot in the study group and dominant foot in the control group were compared, navicular drop ($p<0,001$) foot posture index ($p=0.001$), RCSP angle ($p=0.000$) were higher in the non-affected foot in the study group, it was seen that dorsiflexion ($p=0.049$) and first metatarsal joint extension ($p=0.002$) were significantly higher in the dominant foot of the control group (Table 4.11).

Table 4. 11. Comparison of the non-affected foot and dominant foot

	Study-Control Group						p value
	Non-affected foot			Dominant foot			
	Median	Min.	Max.	Median	Min.	Max.	
Foot posture index	7,00	-4,00	11,00	4,00	-2,00	8,00	p=0,001
dorsiflexion	12,00	6,00	20,00	16,00	8,00	25,00	p<0,001
First MPJ extension	32,50	10,00	45,00	40,00	25,00	60,00	p=0,002
Navicular drop	12,00	9,00	16,00	6,00	4,00	8,00	p<0,001
RCSP angle	10,50	7,00	18,00	5,00	4,00	7,00	p<0,001

Mann Whitney U test

When the FPI, RCSP, NDT, MAS result correlations in the study group were analyzed, there was positive significant relationship between FPI and RCSP and NDT and there was a positive significant relationship between FPI and MAS ($r=0.717$, $r=0.732$, $r=0.603$). It could be stated that as FPI value increased, RCSP, NDT and MAS values will increase as well. There was a positive significant relationship between RCSP and NDT and there was positive weak correlation between RCSP and MAS ($r=0.661$, $r=0.518$). It could be stated that as RCSP value increased, NDT and MAS values will increase as well. There was a weak correlation between NDT and MAS ($r=0.48$). It could be stated that as NDT value increased, MAS value will increase as well.

Table 4. 12. FPI, RCSP, NDT, MAS result correlation in the study group

		FPI	RCSP	NDT	MAS
FPI	r	1	0,732	0,603	0,717
	p		0,000*	0,00*	0,00*
RCSP	r		1	0,661	0,518
	p			0,00*	0,00*
NDT	r			1	0,48
	p				0,00*
MAS	r				1
	p				

*p<0,01 r: correlation coefficient
Spearman Correlation test

When the affected and non-affected foot in the study group were compared, more likely to fail the paper grip test of the lesser toes in the affected foot. (p<0.01) (Table 4.13)

Table 4. 13. Comparison of PGT in the affected and non-affected foot

		Study Group	
		Affected foot F (%)	Non affected foot F (%)
Paper grip test, halluks	successful	11(46)	15(62)
	failed	13(54)	9 (38)
Paper grip test, lesser toes	successful	8 (33)	13(54)
	failed	16 (67)	11(46)

Fisher Exact test p<0.01

When the affected and non-dominant foot were compared, more likely to fail the paper grip test of the lesser toes in the affected foot. (p<0.01) (Table 4.14)

Table 4. 14. Comparison of PGT in the affected and non-dominant foot

		Study-Control Group	
		Affected foot F (%)	Non dominant foot F (%)
Paper grip test, halluks	successful	11(46)	17(71)
	failed	13 (54)	7 (29)
Paper grip test, lesser toes	successful	8 (33)	15(62)
	failed	16 (67)	9 (38)

Fisher Exact test $p < 0.01$

When the non-affected and dominant foot were compared, more likely to fail the paper grip test of the lesser toes in the non-affected foot. ($p < 0.01$)(Table 4.15)

Table 4. 15. Comparison of PGT in the non-affected and non-dominant foot

		Study-Control Group	
		Non affected foot F (%)	Dominant foot F (%)
Paper grip test, halluks	successful	15(62)	18(75)
	failed	9 (38)	6 (25)
Paper grip test, lesser toes	successful	13(54)	15(62)
	failed	11(66)	9 (38)

Fisher Exact test $p < 0.01$

When the affected foot in the case group was evaluated, among individual's faller and non-faller, there was no statistically significant difference for foot function total score and sub-scores and first MPJ extension angle. Dorsiflexion angle was significantly higher in non-fallers. However, foot posture index ($p = 0.008$) was significantly higher in patients with navicular drop ($p = 0.001$) and RCSP angle ($p = 0.037$) fallers. (Table 4.16).

Table 4. 16. Comparison of with and without history of falling of the affected foot

	Falling history						p value
	yes			no			
	Median	Min.	Max.	Median	Min.	Max.	
FPI	8,50	-2,00	12,00	6,00	-4,00	8,00	p=0,008
FFI total score	20,00	5,00	40,00	20,00	5,00	30,00	p>0,05
FFI pain	2,00	0,00	6,00	2,00	0,00	5,00	p>0,05
FFI disability	10,00	1,00	14,00	7,00	3,00	12,00	p>0,05
FFI activity	6,50	1,00	32,00	6,50	2,00	20,00	p>0,05
dorsiflexion	9,00	6,00	16,00	12,50	6,00	18,00	p=0,001
First MPJ extension	20,00	5,00	30,00	21,50	10,00	30,00	p>0,05
Navicular drop	16,00	8,00	18,00	13,00	7,00	16,00	p=0,001
RCSP angle	13,00	10,00	20,00	11,00	8,00	15,00	p=0,037

Mann Whitney U test

When the non-affected foot in the case group was evaluated, among individuals with and without falling history, there was no statistically significant difference for foot function total score and sub-scores, and first metatarsal extension angle. Dorsiflexion angle was significantly higher in non-fallers. (p=0.001) However, foot posture index (p=0.003) was significantly higher in patients with navicular drop (p=0.001) and RCSP angle (p=0.032) history (Table 4.17).

Table 4. 17. Comparison of with and without history of falling of the non-affected foot

	Falling history						p value
	yes			no			
	Median	Min.	Max.	Median	Min.	Max.	
FPI	9,00	-2,00	12,00	6,00	-4,00	7,00	p=0,003
FFI total score	20,00	5,00	40,00	20,00	5,00	30,00	p>0,05
FFI pain	2,00	0,00	6,00	2,00	0,00	5,00	p>0,05
FFI disability	10,00	1,00	14,00	7,00	3,00	12,00	p>0,05
FFI activity	6,50	1,00	32,00	6,50	2,00	20,00	p>0,05
dorsiflexion	10,00	6,00	16,00	13,00	6,00	20,00	p=0,001
First MPJ extension	32,50	10,00	40,00	32,50	14,00	45,00	p>0,05
Navicular drop	15,00	7,00	18,00	12,50	4,00	14,00	p=0,001
RCSP angle	12,50	9,00	18,00	10,00	7,00	15,00	p=0,032

Mann Whitney U test

When the affected and non-affected foot in the case group were compared, there was no statistically significant difference between the two groups in terms of hallux valgus existence ($p>0.05$) (Table4.18).

Table 4. 18. Comparison of HV in the affected and non-affected foot

		Study Group	
		Affected foot F (%)	Non-affected foot F (%)
Hallux valgus	yes	20(83)	19(79)
	no	4 (17)	5 (21)

Fisher Exact test $p>0.05$

In affected foot in the study group, halluks valgus existence was higher in number in the non-dominant foot in the control group ($p=0.000$) (Table 4.19).

Table 4. 19.Comparison of HV in the affected and non-dominant foot

		Study-Control Group	
		Affected foot F (%)	Non-dominant foot F (%)
Halluks valgus	yes	20 (83)	10 (42)
	no	4 (17)	14 (58)

Fisher Exact test $p<0.001$

In non-affected foot in the case group, hallux valgus was higher than the dominant foot in the control group ($p=0.000$). (Table 4.20).

Table 4. 20. Comparison of HV in the non-affected foot

		Study-Control Group	
		Non-affected foot F (%)	Dominant foot F (%)
Halluks valgus	yes	19 (79)	10 (42)
	no	5 (21)	14 (58)

Fisher Exact test $p<0.001$

5. DISCUSSION and CONCLUSION

Stroke is a syndrome that progresses rapidly after blood flow in the brain with focal or global disorder results. Stroke is the third most frequent mortality reason around the world after cancer and cardiovascular diseases and at the same time, it is the top disease that causes disability. After the stroke, 50-65% of the patients experience permanent disability (2). Cognitive function, communication, motor and sensory deficiencies impact the daily lives of individuals and decrease life quality. Therefore, stroke patients must be evaluated in detail from every perspective by considering functional independence and daily life activities. The purpose of the post-stroke period is to ensure maximum functional independence and minimum disability.

After a stroke, due to musculoskeletal system or neurologic system anomalies, there might be changes in plantar sensation in foot structure, foot posture, range of motion, foot strength and foot functions. Such structural deformations of the foot bring together functional changes. These deformities damage preserving bilateral lower extremity and body balance and might lead to abnormal changes in the general walking pattern in the musculoskeletal system falls and pain (6). This study supports the increasing evidence that shows structural changes in the foot and ankle of individuals with a stroke can affect functional independence and balance (12-14).

After a stroke, the sensory impairment is frequently encountered. Somatosensorial system impairment prevent feedback from the sensory system and cause negative effects on motor skills. It is believed that sensory input from the plantar surface of the foot contributes to body posture stability and balance (3, 30). In this study, when the non-affected and affected foot of individuals with stroke were compared, it was seen that sensation impairment on the affected side was at 66.6% level. When the foot of individuals with stroke and healthy controls compared, it was seen that sensation impairment %12 in the healthy controls. According to Gorst et al. (21), the ratio of the first metatarsal joint somatosensory deficit among 163 patients that experienced chronic stroke was 56%. Robinson et al. (4) stated that when 30 individuals with ambulatory stroke patients were considered, %13 of these patients showed proprioception abnormality which was revealed after the first metatarsal joint movement detection measurement with manual tests. General opinions show that sensory functional disorders

are common after a stroke. Accordingly, the results of this study are in line with the related literature. Different ratios compared to results reported in other studies might be caused by subjective assessment and a variety of applied methods.

In this study that analyzed foot and ankle characteristics of individuals with stroke, navicular drop test (NDT), foot posture index (FPI) and resting calcaneal stance position test (RCSP) frequently applied in the related literature with necessary reliability and validity studies have been adopted to compare the foot shapes and to determine the foot posture. The navicular drop test was first defined by Brody and it is a common, reliable and valid measurement method in the literature (97). Menz defined the most convenient measurement methods for foot pronation as navicular drop test (69). According to Brody, while navicular drop values below 10 mm are normal for the adult, values above 15 mm are classified as abnormal (97). When both the non-affected foot and affected foot of individuals with stroke and non-dominant foot of healthy individuals and affected foot of the individuals with and without falling history were compared, navicular drop height showed statistically significant difference. When patients with stroke changed their positions from neutral subtalar joint position to standing upright position, drop on the affected side was higher than the non-affected side and healthy control group. This might have several reasons. In this study, it was seen that the foot posture of the stroke group with falling history had more pronation than stroke group without falling history and stroke group had more pronation than the healthy control group. Additionally, when the non-affected foot was compared with the dominant foot of healthy individuals without stroke, it was seen that navicular drop amount (NDT) was higher. This might be caused by non-affected extremity to carry the majority of the body mass. Sackley et al. reported that 61 to 80% of the body mass of the stroke patients were carried by the non-affected lower extremity (69).

Another method applied to determine the foot posture was the foot posture index (FPI). When the affected foot and non-affected foot were compared, there was no statistically significant difference. When the affected foot was compared with the healthy control group without stroke, FPI score was higher. This might show that the foot posture of individuals with stroke might have pronation than healthy individuals.

Decreases sensory input on the foot plantar surface after the stroke might lead to foot posture changes. To increase the decreased sensory input, the force on the lateral

section of the foot decrease and the force on the foot plantar surface and thumb increase might increase pronation (31). This might be a compensation mechanism to increase postural stabilization with foot stance position (32). Non-affected FPI results were found to be higher than the dominant side results of the healthy control group. These results showed that due to decreased postural control linked with the pronation on the affected side increased due to intrinsic muscle imbalance on the foot of individuals with stroke caused the non-affected foot to be subjected to more body mass. Therefore, the non-affected side might have an arc drop since individuals with stroke put more weight on the non-affected foot. The related literature has no studies showing foot supination in individuals with stroke (14). However, our results are similar to other studies. Forghany et al. studies 72 individuals with stroke and found that pronation was more prevalent among individuals with stroke than supination. Interestingly, FPI norm scores in the previous studies with stroke patients were higher than our study (12, 13-14). The reasons for these scores might be a long time after the stroke in our study, load distribution of chronic stroke on the foot over time and the possibility of effects that change the posture. FPI results of the healthy control group without stroke were similar to FPI results of healthy individuals in Redmond et al. (15). In this study, stroke patients with falling history had higher foot posture index scores than patients without falling history. This showed individuals who fall had higher pronation. Menz et al. investigated the relationship between foot posture and distorted balance and emphasized that high foot posture index values might increase the falling risk in elders (3). It is believed that foot posture distortions such as pronation decrease the ability to preserve postural stability and lead to balance problems and falling. Since the pronation foot posture fails to provide complete mechanical support, it fails to create joint stability when transferring weight to the foot. This change in the foot structure affects the harmony of the foot and ankle. This changes the joint sequence and the angles with foot and leads to postural control problems (121). The related literature has studies on FPI scores of individuals with stroke and elder individuals with falling history (12, 13-3). However, there was no specific study showing FPI norm values for individuals with stroke and falling history. Angin et al. investigated postural sway speed and foot posture in a healthy population and found that postural sway speed was higher in pronation foot when the eyes were closed. It was reported that while the normal foot can neutralize the gravitational center with sufficient and correct postural sway strategies, foot in the pronation increased postural sway due to increased plantar

pressure and distorted sensation (120). Another study in line with these results argues that foot posture at pronation had weaker postural sway control (122). In another study, it was reported that the oscillation speed of less plantar contact foot was increased and this was caused by the decreased sensory input (124). Tsai et al. remarked that in the pronation foot, foot stability was distorted when prone to subtalar joint and resulted in joint hypermobility, decreased sole contact, decreased sensory input and distorted postural control. It was emphasized that pronation foot posture showed weaker postural control than the neutral foot and affected the balance (10).

Resting calcaneal stance position (RCSP) test is another method to evaluate foot posture. Based on the results of this study, ankle joints of the patients with stroke generally had pronation. This was supported by the strong correlation between RCSP and FPI. Barnes et al. reported that lower extremity spasticity leads to abnormal muscle tension with antagonist contraction and this might be beneficial for standing still position and postural control, however, it is the main reason that makes walking challenging (16). In this study, pronation levels of stroke patients have a high MAS test score. As correlating with other tests, the higher spasticity degrees lead to higher foot pronation. At the same time, it was seen that as navicular drop amount increases, spasticity and ankle pronation were higher. In this case, as the level of spasticity increases, calcaneus slope might increase strongly. NDT and FPI test results showed a strong correlation. This shows that as the navicular drop amount increases, the foot has more pronation. The results of this study match with Dillis et al. showed a high correlation between the navicular drop and foot pronation (17). Park et al. reported that stroke patients had higher weight increase in the anterior and medial side of the foot and this caused bearing the increasing weight harder (18). According to this study, it is believed that increasing spasticity due to stroke changed the foot posture with navicular bone position change and lead to foot pronation and abnormal weight load. It was seen that these changes were closely related to each other and showed a correlation. RCSP test results indicated that the lateral location of the calcaneus was related to higher spasticity, higher navicular drop amount and more foot pronation. These results showed that structural foot deformities due to stroke were caused by various factors and these factors had correlations. The data of this study provided information about structural changes in the foot and ankle of stroke patients. Since the test results determining the foot posture correlated and these tests were easily and rapidly

applied in the clinic setting, therapeutic strategies might be used for the patients and these results, at the same time, can form the basis of future studies.

In this study, ankle range of motion was measured with goniometric measurement. This method is easy to apply measurement commonly used in the literature. In this study, while the affected foot dorsiflexion angle of the individuals with stroke was slightly lower, there was no significant difference compared to the non-affected foot. However, when compared with healthy individuals without this condition, DF angle of both affected and non-affected foot was clearly lower. When the stroke group was compared for having or not having a falling history, DF angle was found low. Lamontagne et al. reported that more than half of the individuals with stroke had decreased dorsiflexion on the affected side during the swing phase of the walking. Decreased dorsiflexion might be caused by dorsal flexor weakness caused by plantar flexor spasticity and foot pathology (36). It might be considered that decreased ankle dorsiflexion might affect functional ability (3). Menz et al. investigated foot ankle characteristics of 176 elderly individuals and found that ankle dorsiflexion angle was related to balance and functional ability (3). Mecagni et al. investigated 34 elderly women for range of motion and found a strong relationship between foot dorsiflexion and balance. It was reported that decreases support from ankle range of motion to changing gravitational center might distort the balance (129). In this study, stroke patients with a falling history had a lower ankle ROM compared to stroke patients without stroke which supports the other studies.

By using the goniometric method, dorsiflexion of the first metatarsophalangeal joint was measured in non-weight-bearing position without supine weight transfer and reliability and validity of this method were reported in previous studies (24). The dorsiflexion of the first metatarsophalangeal joint of the affected foot (40°) had a lower angle than the non-affected foot (45°). The dorsiflexion of the first metatarsophalangeal joint of both feet of individuals with stroke was lower than the healthy control group (52°). Root et al. reported 65° extension for a normal walk (24). In this study, the high average age might be the reason for not meeting this value in both groups. Menz et al. reported that the dorsiflexion of the first metatarsophalangeal joint had decreasing values with old age and this limited the functional mobility ability (3, 4, 15). Since the individuals included in this study were in the same age group, the results support these studies. On the other hand, it was seen that the sensory input of the patients with stroke was decreased

compared to the healthy control group as shown by the sensory test conducted on the plantar surface of the first MPJ. It might be suggested that decreases ROM might be caused by decreased thumb position sensation.

Hallux and lesser toe plantar flexor muscle strength were assessed with paper grip test. In this study, lesser toe flexor muscle strength in the affected and non-affected foot of individuals with stroke was found weaker than the control group. While the failed paper grip test ratio of individuals with stroke was 55% and 37% in hallux, this was 66% and 45% in lesser toes. In the control group, hallux and lesser toe failed paper grip test results were 30% and 37%. Previous studies have reported that foot toe plantar flexor muscle strength might decrease with old age (30). The results of our study are in line with the reported failed paper grip test results for the elderly population. There are no specific results reported for individuals with stroke in the literature. Menz et al. stated that paper grip test results were in line with muscle strength results obtained from plantar pressure platform (113). It was shown that toe plantar flexor strength was related to the toe pressure during walking (65). According to the literature, toe muscle function can play an important role in preserving the balance for elderly individuals (65, 66). Endo et al. reported a strong correlation between toe plantar flexor muscle strength and maximal balance range (32). Tanaka et al. stated that during standing, older people applied more pressure on toes compared to younger people (33). Toes play an important role to stabilise the body when the gravitational center change both while standing and walking. Therefore, decreased gripping ability of the toe might contribute to decreased balance.

In this study, the foot function index (FFI) was applied to functionally assess the foot of stroke patients. The high reliability and validity of the foot function index were proved and this method has been reported as the commonly applied method (10). Total foot function index scores and pain, disability, activity limitation sub-scores of the individuals with stroke were higher than individuals without stroke. There are few studies specifically evaluating FFI on individuals with stroke. Menz et al. conducted a study on elderly individuals and reported that foot ache and foot functions might impact daily life activities and functional independence (5). Kavlak et al. studies on males living in a residential home and found that foot function index scores of these individuals were high (8). It might be argued that foot functions deteriorate in elderly individuals, however, this

is seen more clearly in individuals with stroke and the foot functions of a stroke patient is worse than a healthy individual at the same age.

In this study, hallux valgus existence and level were measured with “The Manchester Scale”. Reliability and validity study of the scale was completed (90). In this study, 20 individuals had mild level hallux valgus was observed among 24 individuals with stroke and 10 individuals had mild level HV among 24 healthy individuals in the control group. It is known that in hallux valgus pathology, various intrinsic and extrinsic factors are effective and gender and stroke are the most important intrinsic factors (6, 7, 8). Majority of the individuals with stroke group consisted of females. This leads that higher HV in the control group might be caused by the gender rather than the stroke. Roddy et al. reported that hallux valgus prevalence in women was 2.64 times higher than men (100). While the deformity can be seen in any age group, it is known that deformity increases with age. Scott et al. analyzed age-related foot deformity and revealed that 30% of elderly participants had mild, 24% had moderate intensity hallux valgus deformity (102). Roddy et al. analyzed the relationship between hallux valgus and age in women and stated that the incidents had 3.5 times higher change after 60 years old (100). When the high age average of the participants was considered, high HV rates were not surprising. There was no significant difference between the affected and non-affected foot of individuals with stroke. Additionally, there was no significant difference between HV levels of stroke group and the healthy control group. In line with the studies in the literature, it is possible to state that HV is mainly affected by age and gender rather than stroke (100, 102).

The limitations of this study included the limited number of stroke case due to difficulty to find patients with stroke with standard clinical properties and functional level, small sample size, collecting self-reported falling data and subjective foot function assessment. Although there are limitations, the results of this study confirmed that there was a foot problem in individuals with stroke and these problems might lead to falling.

It is clearly known that insufficient and weak postural control of individuals with stroke affected balancing ability and lead to falling. Although functional mobility and balance are known as the main problems in individuals with stroke, there are few studies on why these problems develop and what factors affected these problems. Postural stability and balancing skills in pronation foot of the individuals with stroke decreases.

Foot posture at pronation leads to balance problems and falling. These results should be investigated in future studies with higher numbers of cases. Decreased contact foot surface, joint sequence disruptions, decreased muscle strength, decrease sensory inputs and joint mobility in individuals with stroke negatively affects the functional performance and balance. More information is needed on this topic to effectively plan physiotherapy and rehabilitation approaches. In other words, better knowledge of the foot balance mechanism effect can lead to better treatment strategy identification.



CONCLUSION AND RECOMMENDATIONS

It was found that foot posture determined in individuals with stroke with various methods showed that the posture was in pronation compared to healthy individuals. With navicular drop and resting calcaneal standing test, it was found that foot position was not at subtalar neutral position and test results had correlation. These measurements used for determining the shape of the foot might form the basis for future studies as these measurements are fast and easy-to-apply.

In individuals with stroke, decreased plantar sensation and disrupted loading pattern was found on the affected foot. This inequality in weight transfer leads to bearing more load than normal on the non-affected side in static standing and non-affected foot posture of individuals with stroke show changes such as pronation. These results should be supported with studies including more individuals.

Compared to healthy individuals, individuals with stroke with foot posture in pronation had distorted foot loading pattern, decreased range of motion, sensation impairments and secondary musculoskeletal problems related to spasticity. In individuals with stroke with weight transferring problems, all foot-related parameters should be evaluated for physiotherapy and rehabilitation program as well as foot pronation, foot bone and joint sequences, muscle weaknesses, joint limitations that might lead to balance and functional losses. Physiotherapy and rehabilitation applications that include treatment and exercise programs in line with these results should be emphasized.

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7.APPENDİCİES

Appendix 1. Ethical Approval



Sayı : 37068608-6100-15- 1825
Konu: Klinik Araştırmalar
Etik kurul Başvurusu hk.

13/02/2020

İlgili Makama (Elif Duvarcı)

Yeditepe Üniversitesi Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölümü Prof. Dr. Rasmi Muammer'in sorumlu araştırmacı olduğu "**İnme Geçirmiş Bireylerin Ayak ve Ayak Bileği Karakteristiklerinin İncelenmesi**" isimli araştırma projesine ait Klinik Araştırmalar Etik Kurulu (KAEK) Başvuru Dosyası **(1808)** kayıt Numaralı KAEK Başvuru Dosyası, Yeditepe Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından **12.02.2020** tarihli toplantıda incelenmiştir.

Kurul tarafından yapılan inceleme sonucu, yukarıdaki isimi belirtilen çalışmanın yapılmasının etik ve bilimsel açıdan uygun olduğuna karar verilmiştir (**KAEK Karar No: 1166**).

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

Appendix 2. Informed Consent Form

ARAŞTIRMA AMAÇLI ÇALIŞMA İÇİN AYDINLATILMIŞ ONAM FORMU

İnme geçirmiş bireylerle ilgili bir çalışma yapmaktayız. Araştırmanın ismi “İnme geçirmiş bireylerin ayak ve ayak bileği karakteristikleri ve düşme öyküsü olan ve olmayan inmeli bireylerin ayak ve ayak bileği karakteristiklerinin karşılaştırılması” dır. Sizde bu araştırmaya katılmanızı öneriyoruz. Ancak hemen söyleyelim ki bu araştırmaya katılıp katılmamakta serbestsiniz. Çalışmaya katılım gönüllülük esasına dayalıdır. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuyup anladıktan sonra araştırmaya dahil olmak isterseniz formu imzalayınız. Bu araştırmayı yapmak istememizin nedeni, inme geçirmiş bireylerin ayak postürlerinin sağlıklı bireylerle karşılaştırarak farklılıkları ortaya koymaktır. Bu çalışma, çalışmakta olduğum Gülen Çocuklar Özel Eğitim Merkezi’nde gerçekleştirilecek olan bu çalışmaya katılmanız araştırmanın başarısı için önemlidir. Eğer araştırmaya katılmayı kabul ederseniz Fzt. Elif Duvarcı tarafından değerlendirileceksiniz. Değerlendirme kayıtlarınız kimliğiniz belirtilmeden sağlık alanında öğrenim gören öğrencilerin eğitiminde veya bilimsel nitelikte yayınlarda kullanılabilir. Bunun dışında bu kayıtlar kullanılmayacak ve başkalarına verilmeyecektir.

Değerlendirmeler sırasında oluşabilecek riskler:

Çalışma kapsamında yapılacak olan değerlendirmeler herhangi bir risk içermemektedir. Bu çalışmaya dahil olmanız için sizden herhangi bir ücret istenmeyecektir. Çalışmaya dahil olduğunuz için size ek bir ödeme de yapılmayacaktır. Bu çalışmaya dahil olmayı reddedebilirsiniz. Bu araştırmaya katılmak tamamen isteğe bağlıdır ve reddettiğiniz takdirde uygulanan değerlendirmede herhangi bir değişiklik olmayacaktır. Yine çalışmanın herhangi bir aşamasında onayınızı çekmek hakkına da sahipsiniz.

Yapılacak çalışmanın getireceği olası yararlar:

Böyle bir çalışma inme geçirmiş bireylerin ayak yapılarındaki bozuklukları ve yol açtığı fonksiyon kayıplarını ortaya koyacaktır. Böylelikle bu çalışmayla, hemipleji geçirmiş bireylerin hastalığın doğasından kaynaklanan yada sonradan edinilen nedenlere bağlı olarak gelişen ayak sorunlarının, düşme öyküsü olan ve olmayan inmeli bireylerdeki

farklılıkları ortaya konursa, bu kişilerin tedavisi için çalışan sağlık profesyonellerinin özellikle fonksiyonel aktivite performanslarının arttırılmasına yönelik çalışmalarında ayak bileği sorunlarını göz önünde bulundurmaları vurgulanacaktır. Bu çalışmaya dahil edilmeyi reddedebilirsiniz. Bu araştırmaya katılım tamamen isteğe bağlıdır ve reddettiğiniz takdirde tedavi programında herhangi bir değişiklik olmayacaktır. Yine çalışmanın herhangi bir aşamasında onayınızı çekmek hakkına da sahipsiniz.

(Katılımcının/Hastanın Beyanı) Sayın Fzt. Elif Duvarcı tarafından bir araştırma yapılacağı belirtilerek bu araştırma ile ilgili yukarıdaki bilgiler bana aktarıldı. Bu bilgilerden sonra böyle bir araştırmaya “katılımcı” (denek) olarak davet edildim. Eğer bu araştırmaya dahil olursam, bana ait bilgilerin gizliliğine bu araştırma sırasında da büyük özen ve saygı ile yaklaşılabileceğine inanıyorum. Araştırma sonuçlarının eğitim ve bilimsel amaçlarla kullanımı sırasında bana ait kişisel bilgilerin ihtimamla korunacağı konusunda bana yeterli güven verildi. Projenin yürütülmesi sırasında herhangi bir sebep göstermeden araştırmadan çekilebilirim. (Ancak araştırmacıları zor durumda bırakmamak için araştırmadan çekileceğimizi önceden bildirmemim uygun olacağına bilincindeyim) Ayrıca benim tıbbi durumuna herhangi bir zarar verilmemesi koşuluyla araştırmacı tarafından araştırma dışı tutulabilirim. Araştırma için yapılacak harcamalarla ilgili herhangi bir parasal sorumluluk altına girmiyorum. Bana da bir ödeme yapılmayacaktır.

Araştırma ile ilgili bir durumda herhangi bir saatte Fzt. Elif Duvarcı’yı 05348861560 no’lu (cep) nolu telefonundan arayabileceğimi biliyorum. Bu araştırmaya katılmak zorunda değilim. Araştırmaya dahil edilmem konusunda zorlayıcı bir davranışla karşılaşmış değilim. Eğer katılmayı reddedersem, bu durumun benim tıbbi bakımına ve fizyoterapist ile olan ilişkisine herhangi bir zarar getirmeyeceğini de biliyorum. Bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Kendi başıma belli bir düşünme süresi sonunda adı geçen bu araştırma projesinde “katılımcı” (denek) olarak dahil edilme kararını aldım. Bu konuda yapılan daveti büyük bir memnuniyet ve gönüllülük içerisinde kabul ediyorum. İmzalı bu form kağıdının bir kopyası bize verilecektir.

Katılımcı

Adı, soyadı: Adres: Tel. İmza

Görüşme tanığı

Adı, soyadı: Adres: Tel. İmza:

Katılımcı ile görüşen fizyoterapist Adı soyadı: Elif Duvarcı Ünvanı: Fizyoterapist

E-mail: elifduvarci@hotmail.com

Tel : 05348861560 İmza



Appendix 3. Foot Function Index

Ayak Fonksiyon İndeksi

Bu sorgu formu ayak ağrınızın günlük yaşamda yapabileceklerinizi nasıl etkilediğine dair bilgi vermek için oluşturulmuştur. Aşağıdaki soruları (GEÇEN HAFTA BOYUNCA ayağınızı en iyi tarif edecek şekilde) cevaplamanızı ve her bir soruya skala üzerinde 0 (ağrı veya zorluk yok) ile 10 (hissedilebilecek en şiddetli ağrı veya yapılamayacak kadar zor) arasında puan vermenizi istiyoruz. Lütfen her soruyu okuyunuz, seçtiğiniz numarayı tablo üzerinde X ile işaretleyiniz. Sağ ve sol ayak şikayetleriniz farklı ise takip eden kutulara 0 ile 10 arasında bir puan veriniz.

AĞRI: AYAK AĞRINIZ NE KADAR ŞİDDETLİ?

1. Ayak ağrınız en fazla olduğunda ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

2. Sabahları ayak ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

3. Yalın ayak yürürken ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

4. Yalın ayak ayakta dururken ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

5. Ayakkabı ile yürürken ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

6. Ayakkabı ile ayakta dururken ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

7. Tabanlıkla yürürken ayak ağrınız ne kadar şiddetli? (Tabanlık kullanmıyorsanız boş bırakınız)

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

8. Tabanlıkla ayakta dururken ayak ağrınız ne kadar şiddetli? (Tabanlık kullanmıyorsanız boş bırakınız)

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

9. Akşam saatlerinde ağrınız ne kadar şiddetli?

Ağrı yok	0	1	2	3	4	5	6	7	8	9	10	Olabilecek en şiddetli ağrı	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

YETERSİZLİK: NE KADAR ZORLUK ÇEKİYORSUNUZ?

1. Ev içinde yürürken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

2. Dışarıda düzgün olmayan yüzeylerde yürürken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

3. 300 metre yol yürüdüğünüzde ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

4. Merdiven çıkarken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

5. Merdiven inerken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

6. Ayak parmaklarınızın ucunda dururken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

7. Sandalyeden kalkarken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

8. Kaldırımdan çıkarken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

9. Hızlı yürürken ne kadar zorluk çekiyorsunuz?

Zorluk yok	0	1	2	3	4	5	6	7	8	9	10	Yapılamayacak kadar zor	SAĞ	SOL
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐			

8.CURRICULUM VITAE

Kişisel Bilgiler

Adı	Elif	Soyadı	Duvarcı
Doğum Yeri	Adana	Doğum Tarihi	29.04.1990
Uyruğu	Tr	TC Kimlik No	12961257126
E-mail	elifduvarci@hotmail.com	Tel	0534 886 1560

Öğrenim Durumu

Derece	Alan	Mezun Olduğu Kurumun Adı	Mezuniyet Yılı
Doktora			
Yüksek Lisans	Fizyoterapi ve Rehabilitasyon	Yeditepe Üniversitesi	2020
Lisans	Fizyoterapi ve Rehabilitasyon	Yeditepe Üniversitesi	2015
Lise	Sayısal	Osmaniye Fen Lisesi	2009

Bildiği Yabancı Dilleri	Yabancı Dil Sınav Notu (#)
İngilizce	YDS 70

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

İş Deneyimi (Sondan geçmişe doğru sıralayın)

Görevi	Kurum	Süre (Yıl - Yıl)
Fizyoterapist	Ümraniye Özel Eğitim ve Rehabilitasyon Merkezi	2018- Halen
Fizyoterapist	Avrasya Hastanesi	2016-2018

