

SMART PHONE-BASED APPLICATION FOR EVALUATION AND  
REHABILITATION OF HINDFOOT PAIN

by

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SMART PHONE-BASED APPLICATION FOR EVALUATION AND  
REHABILITATION OF HINDFOOT PAIN

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*To my family...*

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## **ABSTRACT**

### **SMART PHONE-BASED APPLICATION FOR EVALUATION AND REHABILITATION OF HINDFOOT PAIN**

Hindfoot pain (HP) affects the population ranges from 4 to 20 percent, and over half of these report disabling pain. The primary aim of our study was to investigate the implementation exercises programmes of the developed web-based smartphone enabled tele-rehabilitation systems compared to the home-based telerehabilitation and conventional physiotherapy approaches. Secondary was to develop analysis systems that can be remotely evaluate ankle ROM and foot deformity with smartphone applications (DijiA & Ardayak) and to investigate its reliability with the universal goniometer (UG) and the SIDAS Analysis machine respectively. According to our aims, I) hindfoot pain patients ( N=77 with 120 feet), II) smartphone applications pilot tests volunteers; a) healthy university students (N=22 with 44 feet) for ROM- DF and PF measurement (DijiA), b) patients with foot deformity (N=14 with 28 feet) for detection of the foot deformity (ArdAyak) were admitted in this study. HP patients were randomised into three different rehabilitation programmes a) conventional physiotherapy, b) home-based rehabilitation, and c) tele-rehabilitation programs. The outcomes of HP patients' pain, disability, function and kinesiophobia were assessed at pre-post intervention (8th week). The reliability of DijiA in ankle joint dorsiflexion and plantarflexion ROM measurement compared with universal goniometer (UG) ROM and ArdAyak foot deformity detection analysis compared with SIDAS Custom Analysis device were tested. Conventional physiotherapy for PFs had significant improvement in functional capacity statistically than others ( $p<.05$ ). Tele-rehabilitation for both pathologies had more significant improvement than the others in terms of kinesiophobia ( $p<.05$ ). Pearson correlation test showed a moderate positive correlation between the DijiA-UG ( $r=.323$  for DF,  $r=.435$  for PF,  $p<.05$ ). The variation in Pearson Correlation Coefficient was showed a moderate positive relationship with  $r$  values of 0.468 for foot deformity ( $p<.05$ ). Conventional physiotherapy program can be recommended for the management of HP. Telerehabilitation may be a more convenient way to apply exercises programmes for kinesiophobia. The promising DijiA & Ardayak apps have the potential to be a appropriate and easy-to-use tool for the assessment of ankle ROM and foot deformity.

## ÖZET

### ARD AYAK AĞRILARININ AKILLI TELEFON TABANLI UYGULAMA İLE DEĞERLENDİRİLMESİ VE REHABİLİTASYONU

Ard ayak ağrısı (AA), popülasyonun yüzde 4 ila 20 unu etkilemekte ve bunların yarısından fazlası disabiliteye neden olan ağrı rapor etmektedir. Çalışmamızın birincil amacı, geliştirilen web tabanlı akıllı telefon kullanımlı sistemler aracılığıyla gerçekleştirilen tele-rehabilitasyon programlarının ev egzersiz ve geleneksel fizyoterapi yaklaşımları ile karşılaştırılmasıdır. İkincisi, akıllı telefon uygulamaları (DijiA & Ardayak) ile ayak bileği eklem hareket açıklığı ve ayak deformitesini uzaktan değerlendirebilen analiz sistemleri geliştirmek ve sırasıyla evrensel gonyometre (EG) ve SIDAS Analiz makinesi ile güvenilirliğini araştırmaktır. Amaçlarımıza göre, bu çalışmaya I) ard ayak ağrısı olan hastalar (N=77 kişi & 120 ayak), II) akıllı telefon uygulamalarının pilot testleri için gönüllüler; a) Dorsifleksiyon (DF) ve plantar fleksiyon (PF) ölçümü (DijiA) için sağlıklı üniversite öğrencileri (N=22 kişi & 44 ayak), b) Ayak deformitesi (N=14 kişi & 28 ayak) tespiti için ayak deformitesi (ArdAyak) için başvuran hastalar kabul edildi. AA hastaları üç farklı rehabilitasyon programına randomizasyon yöntemiyle dahil edildi: a) konvansiyonel fizyoterapi, b) evde rehabilitasyon ve c) tele-rehabilitasyon programları. AA hastalarının ağrı, sakatlık, fonksiyon ve kinezyofobi sonuçları tedavi öncesi-sonrası (8. hafta) değerlendirildi. DijiA'nın güvenilirliği ayak bileği eklemi-DF ve PF ölçümü EG ile ve ArdAyak ayak deformitesi tespit analizi ise ile SİDAS Özel Analiz cihazı ile karşılaştırılarak test edildi. Plantar fasiitli bireyler için geleneksel fizyoterapi, istatistiksel olarak diğer gruplara göre fonksiyonel kapasitede anlamlı farklılıklara sahipti ( $p<.05$ ). Her iki patoloji için tele-rehabilitasyon grubunda bulunan bireyler, kinezyofobi açısından diğerlerine göre daha belirgin bir iyileşme gösterdi ( $p<.05$ ). Pearson korelasyon testi, DijiA-EG arasında orta derecede pozitif bir korelasyon gösterdi (DF için  $r=.323$ , PF için  $r=.435$ ,  $p<.05$ ). Pearson Korelasyon Katsayısı'ndaki varyasyon, ayak deformitesi için  $r=0.468$  değeri ile orta derecede pozitif bir ilişki gösterdi ( $p<.05$ ). Geleneksel fizyoterapi protokolü AA lı bireylerinde tedavisinde kullanılabilir. Egzersiz programlarını tele-rehabilitasyon ile uygulamak kinezyofobi açısından daha uygun bir yol olabilir. Gelecek vaat eden DijiA & Ardayak uygulamaları, ayak bileği eklem hareket açıklığı ve ayak deformitesinin değerlendirilmesi için kullanışlı ve kullanımı kolay bir araç olma potansiyeline sahiptir.

## TABLE OF CONTENTS

|                                                            |     |
|------------------------------------------------------------|-----|
| ACKNOWLEDGEMENTS.....                                      | iv  |
| ABSTRACT.....                                              | v   |
| ÖZET .....                                                 | vi  |
| LIST OF FIGURES .....                                      | ix  |
| LIST OF TABLES.....                                        | xii |
| LIST OF SYMBOLS/ABBREVIATIONS.....                         | xv  |
| 1.INTRODUCTION .....                                       | 1   |
| 2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW .....       | 4   |
| 2.1. Hindfoot Anatomy .....                                | 4   |
| 2.1.1. Bones .....                                         | 5   |
| 2.1.2. Joints .....                                        | 8   |
| 2.1.3. Embryology .....                                    | 13  |
| 2.1.4. Vascular Supply and Lymphatics .....                | 13  |
| 2.1.5. Skin, Subcutaneous and Fascia .....                 | 15  |
| 2.1.6. Nerves .....                                        | 19  |
| 2.1.7. Muscles .....                                       | 19  |
| 2.1.8. Function .....                                      | 20  |
| 2.2. Hindfoot Pain .....                                   | 22  |
| 2.3. Diagnostic Imaging .....                              | 24  |
| 2.4. Associated Conditions.....                            | 24  |
| 2.4.1. Overpronation & Supination and Varus & Valgus ..... | 25  |
| 2.4.2. Haglund's deformity .....                           | 25  |
| 2.4.3. Retrocalcaneal bursitis .....                       | 26  |
| 2.4.4. Calcaneal stress fracture .....                     | 26  |
| 2.4.5. Heel fat pad atrophy.....                           | 26  |
| 2.4.6. Tarsal tunnel syndrome.....                         | 27  |
| 2.4.7. Plantar fasciitis.....                              | 27  |
| 2.4.8. Achilles Tendinopathy .....                         | 30  |

|                                                        |     |
|--------------------------------------------------------|-----|
| 2.4.9. Other Conditions.....                           | 34  |
| 2.5. Treatment Options.....                            | 34  |
| 2.5.1. Conventional Physiotherapy .....                | 34  |
| 2.5.2. Tele-rehabilitation in Physiotherapy.....       | 39  |
| 3.MATERIALS AND METHODS.....                           | 51  |
| 3.1. SUBJECTS.....                                     | 51  |
| 3.1.1. Research Design Processes ( Flow Chart) .....   | 52  |
| 3.2. METHODS .....                                     | 56  |
| 3.2.1. Study Design.....                               | 56  |
| 3.2.2. Interventions ( Procedures and Protocols) ..... | 56  |
| 4.RESULTS .....                                        | 86  |
| 5.DISCUSSION.....                                      | 109 |
| 6.CONCLUSION.....                                      | 117 |
| REFERENCES .....                                       | 119 |
| APPENDIX A.....                                        | 141 |
| APPENDIX B .....                                       | 142 |
| APPENDIX C .....                                       | 144 |
| APPENDIX D.....                                        | 145 |
| APPENDIX E .....                                       | 149 |
| APPENDIX F .....                                       | 150 |
| APPENDIX G.....                                        | 153 |
| APPENDIX H.....                                        | 155 |
| APPENDIX İ .....                                       | 156 |

## LIST OF FIGURES

|                                                                                                                           |    |
|---------------------------------------------------------------------------------------------------------------------------|----|
| Figure 2.1. Compartments of the foot.....                                                                                 | 4  |
| Figure 2.2. Hindfoot anatomy.....                                                                                         | 5  |
| Figure 2.3. Foot anatomy lateral and medial view .....                                                                    | 7  |
| Figure 2.4. Overview of the hindfoot .....                                                                                | 8  |
| Figure 2.5. Overview of the hindfoot joints.....                                                                          | 9  |
| Figure 2.6. Transverse tarsal (chopart) joint.....                                                                        | 12 |
| Figure 2.7. Vascular supply to the talar body .....                                                                       | 15 |
| Figure 2.8. Soft-tissue layers .....                                                                                      | 16 |
| Figure 2.9. Plantar aponeurosis parts (the central (C), medial (M) and lateral (L), medial calcaneal tubercle (MCT) ..... | 17 |
| Figure 2.10. The kinematics of the forefoot according to the hindfoot .....                                               | 21 |
| Figure 2.11. Plantar fasciitis .....                                                                                      | 28 |
| Figure 2.12. Abnormal Achilles tendon magnetic resonance imaging.....                                                     | 31 |
| Figure 2.13. Tendon health domains .....                                                                                  | 33 |
| Figure 2.14. Progression of technology in telerehabilitation.....                                                         | 42 |
| Figure 2.15. Tele-rehabilitation systems revenue and growth rate of USA .....                                             | 44 |
| Figure 2.16. Tele-rehabilitation systems revenue and growth rate of Europe .....                                          | 44 |
| Figure 3.1. Flow chart of the study .....                                                                                 | 53 |
| Figure 3.2. Study protocol for all groups.....                                                                            | 57 |
| Figure 3.3. Visual Analogue Scale (VAS).....                                                                              | 58 |

|                                                                                                                                          |     |
|------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 3.4. Goniometric measurements .....                                                                                               | 60  |
| Figure 3.5. Mobilization with Movement for ankle joint .....                                                                             | 62  |
| Figure 3.6. Myofascial release for Achilles tendinopathy .....                                                                           | 63  |
| Figure 3.7. Myofascial release for plantar fasciitis.....                                                                                | 63  |
| Figure 3.8. Website- <a href="http://www.dijitaladimlar.yeditepe.edu.tr">www.dijitaladimlar.yeditepe.edu.tr</a> .....                    | 70  |
| Figure 3.9. Registration- <a href="http://www.dijitaladimlar.yeditepe.edu.tr">www.dijitaladimlar.yeditepe.edu.tr</a> .....               | 71  |
| Figure 3.10. Registration- <a href="http://www.dijitaladimlar.yeditepe.edu.tr">www.dijitaladimlar.yeditepe.edu.tr</a> .....              | 71  |
| Figure 3.11. Rehabilitation Programmes- <a href="http://www.dijitaladimlar.yeditepe.edu.tr">www.dijitaladimlar.yeditepe.edu.tr</a> ..... | 72  |
| Figure 3.12. Online evaluation forms .....                                                                                               | 73  |
| Figure 3.13. Tele-rehabilitation for Achilles tendinopathy .....                                                                         | 74  |
| Figure 3.14. Tele-rehabilitation for plantar fasciitis .....                                                                             | 75  |
| Figure 3.15. General System Architecture of smartphone applications .....                                                                | 77  |
| Figure 3.16. Applications in patient phone and local database .....                                                                      | 78  |
| Figure 3.17. Mobile Component of the applications .....                                                                                  | 78  |
| Figure 3.18. Communication of smartphone applications with services and database ....                                                    | 79  |
| Figure 3.19. The 2D skeleton model of Dijia app .....                                                                                    | 80  |
| Figure 3.20. Dijital Adımlar application.....                                                                                            | 81  |
| Figure 3.21. Range of motion measurement with Dijia app.....                                                                             | 82  |
| Figure 3.22. ArdAyak smartphone application.....                                                                                         | 83  |
| Figure 3.23. Foot deformity detection with ArdAyak app .....                                                                             | 84  |
| Figure 4.1.The Distribution of Gender .....                                                                                              | 114 |

|                                                                                                                                   |     |
|-----------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 4.2. Changes in Pearson Correlation Coefficient Between the Universal Goniometer and Dijia Smartphone App .....            | 117 |
| Figure 4.3. Distribution of Foot Deformity Diagnosis in SIDAS- custom station Premium .....                                       | 122 |
| Figure 4.4. Changes in Pearson Correlation Coefficient Between the SIDAS- custom station Premium and ArdAyak Smartphone App ..... | 124 |



## LIST OF TABLES

|                                                                                                                                                                                                                                                |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 2.1. Compartments of the foot .....                                                                                                                                                                                                      | 4   |
| Table 2.2. Overview of the ankle joints.....                                                                                                                                                                                                   | 10  |
| Table 2.3. Overview of the subtalar joint .....                                                                                                                                                                                                | 11  |
| Table 2.4. Overview of the transverse tarsal joint .....                                                                                                                                                                                       | 13  |
| Table 2.5. Foot Muscles.....                                                                                                                                                                                                                   | 20  |
| Table 2.6. Structures and sites of pain .....                                                                                                                                                                                                  | 23  |
| Table 2.7. Hindfoot pain pathologies.....                                                                                                                                                                                                      | 24  |
| Table 2.8. Potential economic impact of healthcare market.....                                                                                                                                                                                 | 45  |
| Table 3.1. Exercises program for Achilles tendinopathy.....                                                                                                                                                                                    | 65  |
| Table 3.2. Exercises program for plantar fasciitis .....                                                                                                                                                                                       | 68  |
| Table 4.1. The number of feet in the study populations .....                                                                                                                                                                                   | 99  |
| Table 4.2. The Abbreviation of the study groups .....                                                                                                                                                                                          | 100 |
| Table 4.3. The Physical Characteristic of the Hindfoot Pain Study Group .....                                                                                                                                                                  | 101 |
| Table 4.4. The Physical Characteristic of Patients with Plantar Fasciitis & Achilles Tendinopathy .....                                                                                                                                        | 102 |
| Table 4.5. The Comparison of The Foot Function Index (FFI) Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intragroup Variables in Plantar Fasciitis Patients.....                                                       | 103 |
| Table 4.6. The Comparison of The Victorian Institute Of Sports Assessment –Achilles Questionnaire (VISA-A), Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intragroup Variables in Achilles Tendinopathy Patients ..... | 104 |

|                                                                                                                                                                                                                                                                 |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 4.7. The Comparison of Tampa Scale for Kinesiophobia (TSK) Scores of Intragroup Variables .....                                                                                                                                                           | 106 |
| Table 4.8. The Comparison The Foot and Ankle Ability Measure (FAAM) Scores of Intragroup Variables .....                                                                                                                                                        | 107 |
| Table 4.9. The Comparison of The Foot Function Index (FFI) Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of post- intervention Intergroup Variables of Plantar Fasciitis Patients .....                                                    | 108 |
| Table 4.10. The Comparison of Post-Treatment The Victorian Institute Of Sports Assessment – Achilles Questionnaire (VISA-A), Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intergroup Variables of Achilles Tendinopathy Patients ..... | 109 |
| Table 4.11. The Comparison of Post-treatment Tampa Scale for Kinesiophobia (TSK) Scores of Inter-group Variables .....                                                                                                                                          | 110 |
| Table 4.12. The Comparison of Post-treatment Tampa Scale for Kinesiophobia (TSK) Scores and Visual Analogue Scale (VAS) of Inter-group Variables.....                                                                                                           | 111 |
| Table 4.13. The Comparison The Foot and Ankle Ability Measure (FAAM) Scores of Intergroup Variables .....                                                                                                                                                       | 112 |
| Table 4.14. Dijia Pilot Study Participants’ Descriptive Data .....                                                                                                                                                                                              | 113 |
| Table 4.15. ArdAyak Pilot Study Participants’ Descriptive Data .....                                                                                                                                                                                            | 114 |
| Table 4.16. Summary Statistics For Ankle Range of Motion (ROM) Measurements In The Study Participants .....                                                                                                                                                     | 115 |
| Table 4.17. Pearson Correlation Coefficient Between the Universal Goniometer and Dijia Smartphone App .....                                                                                                                                                     | 116 |
| Table 4.18. Distribution of Answers to the System Usability Scale (SUS) Survey Questionnaire for Dijia Smartphone App .....                                                                                                                                     | 118 |

|                                                                                                                                    |     |
|------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 4.19. The Application Overall Score, Suggestions and Feedback Results for DijiA Smartphone App .....                         | 119 |
| Table 4.20. Summary Statistics For ArdAyak Pilot Study Participants .....                                                          | 120 |
| Table 4.21. A Comparison of Foot Deformity Distribution Between the SIDAS- custom station Premium and ArdAyak Smartphone App ..... | 121 |
| Table 4.22. Pearson Correlation Coefficient Between the SIDAS- custom station Premium and ArdAyak Smartphone App.....              | 123 |



## LIST OF SYMBOLS/ABBREVIATIONS

|             |                                              |
|-------------|----------------------------------------------|
| ADL         | Activities of daily living                   |
| ANOVA       | The one-way analysis of variance             |
| Application | App                                          |
| Astym       | Soft tissue treatment                        |
| AT          | Achilles tendon                              |
| ATpathy     | Achilles tendinopathy                        |
| BMI         | Body Mass Index                              |
| C           | Central parts of the plantar aponeurosis     |
| [CI]        | Confidence interval                          |
| COPD        | Chronic obstructive pulmonary disease        |
| CS          | Calf stretching                              |
| CT          | Computed tomography                          |
| DijiA       | Dijital Adımlar smartphone-based application |
| DF          | Dorsiflexion                                 |
| ESWT        | Extracorporeal shockwave therapy             |
| FAAM        | The Foot and Ankle Ability Measure           |
| FFI         | Foot Function Index                          |
| FHL         | Flexor hallucis longus                       |
| FP          | Foot Pain                                    |
| GCS         | Granulocyte-colony stimulating factor        |
| HA          | Hyaluronic Acid                              |
| HP          | Hindfoot Pain                                |
| HSR         | Slow resistance training                     |
| ICC         | Intraclass correlation coefficient           |
| IPL         | Intense pulsed light                         |
| KVK         | Turkish Personal Data Protection             |
| L           | Lateral parts of the plantar aponeurosis     |
| LCL         | Lateral collateral ligaments                 |

|                |                                         |
|----------------|-----------------------------------------|
| M              | Medial parts of the plantar aponeurosis |
| MCL            | Medial collateral ligaments             |
| MCT            | Medial calcaneal tubercle               |
| mo             | Months                                  |
| MRI            | Magnetic resonance imaging              |
| MTJ            | Myotendinous junction                   |
| MTP            | Myofascial trigger points               |
| MWM            | Mobilizations with Movement             |
| N              | Patient Number                          |
| NSAIDs         | Nonsteroidal antiinflammatory drugs     |
| PF             | Plantar Flexion                         |
| PFa            | Plantar Fascia                          |
| PFs            | Plantar fasciitis                       |
| PFSS           | Plantar fascia-specific stretching      |
| PHP            | Plantar heel pain                       |
| PPT            | Pressure pain thresholds                |
| PRP            | Platelet-rich plasma                    |
| PT             | Physical therapy                        |
| PTB            | Patellar tendon-bearing                 |
| r              | Pearson correlation coefficient         |
| ROM            | Range of motion                         |
| SFE            | Short Foot Exercise                     |
| Str            | Self-stretching                         |
| SUS            | System usability scale                  |
| T <sub>0</sub> | Pre-intervention                        |
| T <sub>1</sub> | 8th week evaluation                     |
| TCE            | Towel Curl Exercises                    |
| TDN            | Trigger point dry needling              |
| TrP            | Trigger point                           |
| TSK            | Tampa Scale for Kinesiophobia           |

|                         |                                                  |
|-------------------------|--------------------------------------------------|
| UG                      | Universal goniometers                            |
| US                      | United States                                    |
| VAS                     | Visual Analogue Scale                            |
| VISA-A<br>Questionnaire | Victorian Institute of Sport Assessment-Achilles |



## 1. INTRODUCTION

Foot pain (FP) is often seen in the general public, with estimates of prevalence range from 17 to 30 percent [1, 2]. According to a comprehensive study, over one-quarter of persons over 45 have regular HP [3]. HP has been associated with the limitation of daily living activities, poor balance, gait problems and health-related quality of life [4, 5]. At least two-thirds of people experience moderate functional daily living issues, according to studies [2, 4, 5].

Aging, female sex, obesity, chronic medical problems (such as osteoarthritis and diabetes), biomechanical factors (excessive external rotation of the lower extremity, increased pronation of the subtalar joint, weakness of plantar flexors, Achilles tendon (AT) shortening), and anatomical changes (pes planus, pes cavus) have been identified as risk factors for hindfoot pain (HP) [6–8]. People with HP have overloaded on bone and soft tissue, foot anatomic disorders, and decreased range of motion (especially ankle DF) [6, 9, 10].

The most common causes of HP are Achilles Tendinopathy (ATpathy) and Plantar Fasciitis (PFs), both of which impact millions of people each year [11, 12]. Most occurrences of HP will cause to more severe and resistant symptoms over time, if not treated [11]. As a result, gathering additional data on prevalence and risk factors in the general population is critical for health-care planning, determining the scope of clinical need and preventing symptoms from entering the refractory period.

Rehabilitation is the process, via which a subject regains strength, relearns skills, or discovers new methods of accomplishing things. For HP sufferers, there are a variety of rehabilitation choices. Tele-rehabilitation, or the distribution of rehabilitation services from a distance, is a viable alternative to traditional rehabilitation programs. Patients may experience exercise behavior in real-world conditions that remain accessible beyond the duration of the in-clinic rehabilitation process, and they can also be developed as computerized versions of various clinical tests. Remote monitoring services, supervised by health-care professionals, can allow patients establish exercise behavior in real-world circumstances that remain accessible beyond the timeframe of the in-clinic rehabilitation process. As a result, there is a growing body of literature on using technology in medicine and rehabilitation for remote evaluation and intervention. Telerehabilitation services may be

delivered using a range of technologies, and a growing number of studies outlines how to use them. Telerehabilitation services may be delivered using a range of technologies, and a growing body of research discusses use of such specialized telerehabilitation technologies to meet the needs of identified client populations. Web and smartphone based technologies are ones of them [13, 14]. In the United States (US), around 90 percent of adults own a phone, with 58 percent preferring smartphones, but in Turkey, 98 percent of individuals own a phone, with 77 percent preferring smartphones [15]. The widespread usage of smartphones has created chances for people to access information and learn new skills through applications [14]. These technologies provide new ways to gather, evaluate, and monitor health information, as well as portability, flexibility, and a wide range of access options [13, 14]. Furthermore, they are able to reach the target population at a reasonable cost [16]. In the literature, they were used in various targeted medical conditions, however; some studies did not specify particular medical conditions and the technology appeared applicable for treatment of a wide range of diseases [17-22]. Several systematic reviews have studied the use of digital programs for various health conditions-pathologies (balance impairment, stroke, cardiac-respiratory diseases, and musculoskeletal disorders) according to the notion of this method (digital technologies utilization) [17–19].

According to reviews, there is little guide of combined physiotherapy interventions for HP includes stretching-strengthening exercises and 'hands-on' therapy. Exercise regimens are an important aspect of HP therapy, and patients must also get feedback from a physiotherapist [10, 11]. Digital technology-based systems are thought to be beneficial for regular follow-up exercises, monitoring alterations, evaluating risk factors and progression. Furthermore, to the best of our knowledge, there is no smartphone app study incorporating hindfoot pathologies with remote risk assessment systems and an exercise program in the literature. As a result, there are two purposes of this study. First one is to investigate and compare the effectiveness of tele-rehabilitation program with home rehabilitation and conventional physiotherapy programs for individuals with hindfoot pain. The second one is to develop analysis systems that can be remotely evaluate ankle range of motion (dorsiflexion & plantar flexion) and foot deformity with smartphone applications and to investigate its reliability with universal goniometer and SIDAS Custom Premium Foot Analysis Machine respectively.

### **Expected Common Impact and Value from Research**

- To assess risk factors, symptoms, duration and locations of individuals with hindfoot pain
- To offer, determine and compare the effective therapeutic options for hindfoot pain patients.
- To develop and investigate the effectiveness of the tele- rehabilitation systems for managing hind foot pain pathologies.
- To ensure the therapeutic option ways that patients perform their exercises and preventive measures (daily life modifications, self-stretching, and myofascial relaxation exercises) regularly and accurately, and to monitor the results.
- To design smartphone application for measuring ankle range of motion and detecting foot deformity and investigate their reliability
- To develop easily and remotely accessible smartphone applications for monitoring foot health status in terms of ankle range of motion and foot deformity.

*H0<sub>a</sub>: There is no difference between the clinical results (pain, functional capacity, kinesiophobia, range of motion) of people with hindfoot pain who underwent three different rehabilitation programmes (conventional physiotherapy, tele-rehabilitation and home-based rehabilitation)*

*H1<sub>a</sub>: There are differences between the clinical results (pain, functional capacity, kinesiophobia, range of motion) of people with hindfoot pain who underwent three different rehabilitation programmes (conventional physiotherapy, tele-rehabilitation and home-based rehabilitation)*

*H0<sub>b</sub>: The smartphone application (DijiA) is not reliable for assessing ankle range of motion compared to the universal goniometer.*

*H1<sub>b</sub>: The smartphone application (DijiA) is reliable for assessing ankle range of motion compared to the universal goniometer.*

*H0<sub>c</sub>: The smartphone application (ArdAyak) is not reliable for evaluating foot deformity compared to SIDAS Custom Station Premium Analysis Machine.*

*H1<sub>c</sub>: The smartphone application (ArdAyak) is reliable for evaluating foot deformity compared to SIDAS Custom Station Premium Analysis Machine.*

## 2. THEORETICAL FRAMEWORK AND LITERATURE REVIEW

### 2.1.HINDFOOT ANATOMY

Foot is a involved structure made up of over twenty six bones, thirty joints, several ligaments, tendons, and muscles responsible for standing upright, enabling the weight of all body and supplied the basis for bipedal gait mechanism [20]. Foot is divided into hind, mid, and forefoot and corresponds to the distal ankle of the lower limb [20].

Table 2.1. Compartments of the foot

| Foot compartments |                                                   |
|-------------------|---------------------------------------------------|
| Forefoot          | phalanges & metatarsals                           |
| Midfoot           | 5 tarsal , 3 cuneiforms, navicular & cuboid bones |
| Hindfoot          | 2 tarsal bones, the calcaneus & talus.            |

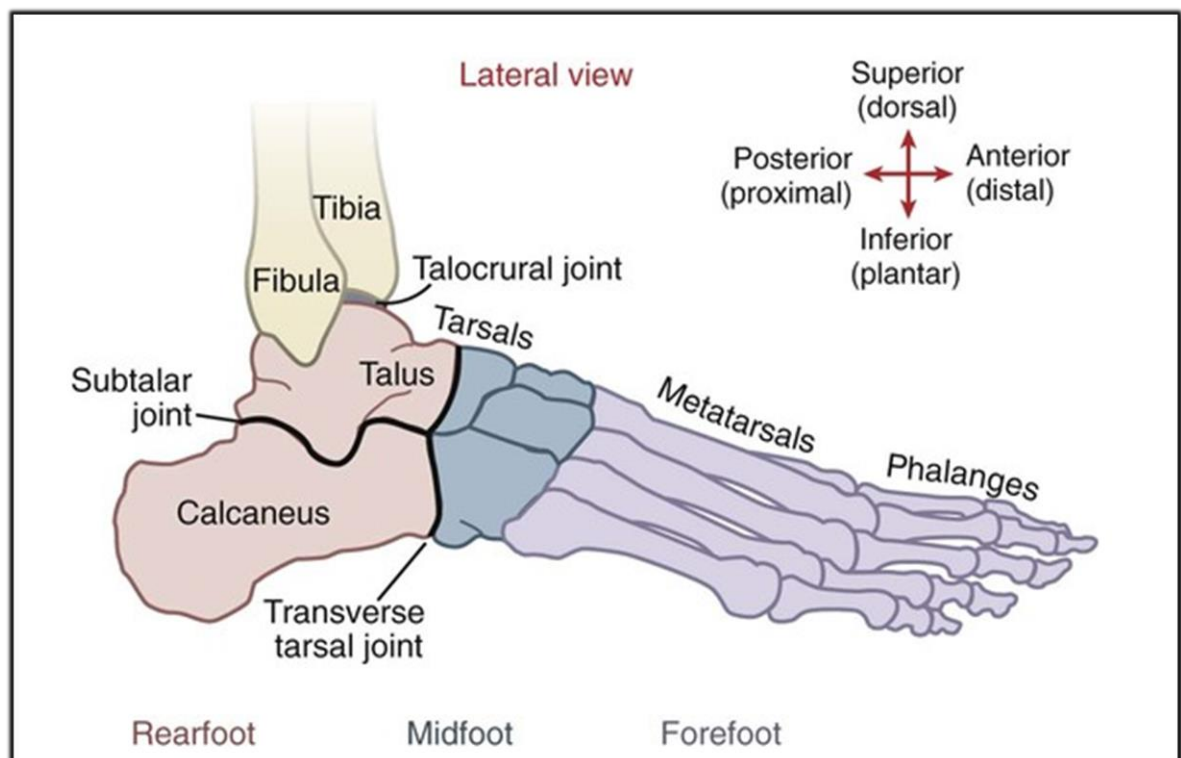


Figure 2.1. Compartments of the foot [27]

### 2.1.1. Bones

The hindfoot, also named as the rear-foot, is posterior part of the foot as separated from mid-forefoot [12, 20]. Hindfoot comprises calcaneus and talus, their articulations, and the bounding soft tissue elements [12, 21]. The hindfoot joins the ankle joint to the more proximal of lower extremity that is deprived of the talus, tibia and fibula [12, 21].

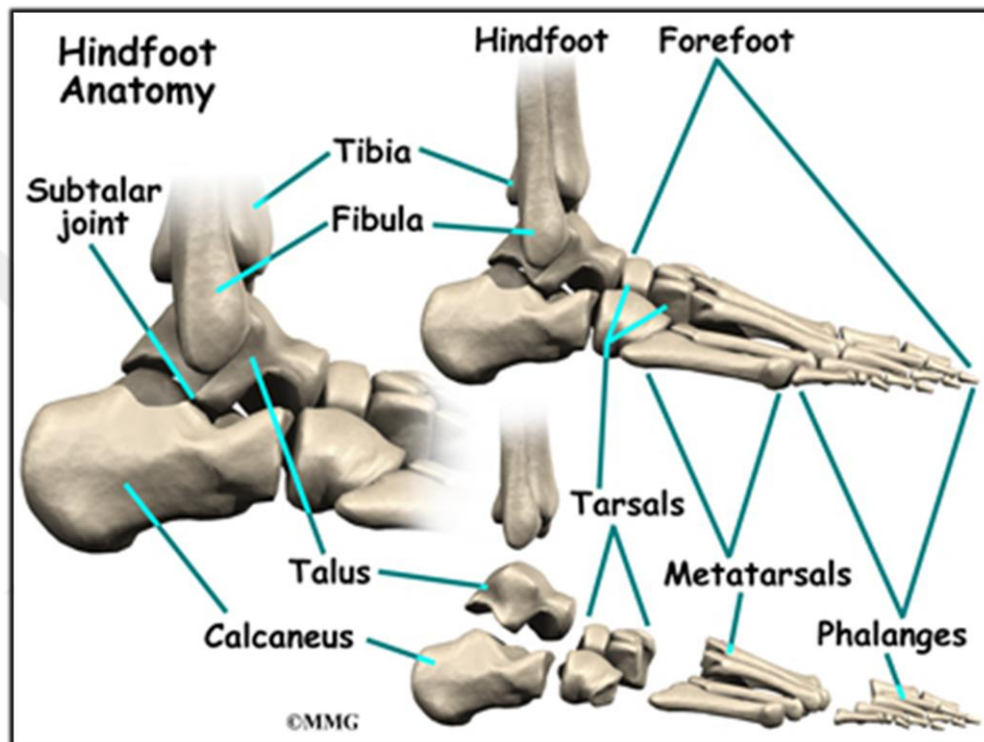


Figure 2.2. Hindfoot anatomy [29]

#### **Tibia and fibula (long bones)**

The foot is objected to the body whereabouts the talus articulates with the tibia- fibula. Generally, tibia is responsible for approximately 85 percent of body weight support. The fibula remains 15 percent; its primary role is to work as the lateral wall of the ankle mortise [20, 22]. The tibia- fibula are get together by the tibio-fibular syndesmosis, a gathering of five ligaments. The peak the distal tibia medial side is named as the medial malleolus; the the fibula distal aspect is named as the lateral malleolus [21–23].

## **Talus**

Talus is the proximal upper foot bone and the second largest tarsal bone. It inclines infero-medially ending as cartilage in head that articulates with the navicular [12, 20]. Talus is commonly thought as 3 parts: the head, the body, and the neck. The talar head is close to the navicular bone to constitute talonavicular joint. The talar body that is thereabout square in shape and is covered by the dome, links the talus to the lower leg at the ankle joint. The talar body is made up of various facets that articulate with the calcaneus at the subtalar joint: postero-lateral and sustentaculum tali (middle facet), medially placed, and anterior facet, antero-medially positioned [20, 21]. Dome of talus is the articular surface of the tibio-talar joint and is located on the top section of the talar body. Talar neck is located between the head and body of the talus. Talar neck is one of number surfaces of the talus not enclosed with cartilage, and is hereby the point of entrance for the blood vessels supplying the talus. The top of the tarsal canal, which laterally opening as the sinus tarsi, is located between the head and body of the talus. Tubercles of the medial and lateral tubercles make up talus posterior process, with the flexor hallucis longus (FHL) tendon resting in groove between them. A Stieda process is a natural anatomic variant of an extended lateral tubercle. The aspect of the joint capsule connection and ligamentous structures is represented by an osseous spur in the distal section of the talar neck. It articulates with other bones, and hyaline (joint) cartilage covers 70 percent of the talus. [20, 21, 24].

The subtalar joint connects the talus to the calcaneus on the bottom, while the talo-navicular joint connects the talus to the navicular on the distal side. The foot can readily rotate around the talus because to these articulations. The talus has a rather poor blood supply due to the fact that no tendons attach to it and the majority of its surface is cartilage. Due to the lack of a strong blood supply, injuries to this bone take much longer to heal than injuries to other bones, and some injuries do not heal at all [20, 22].

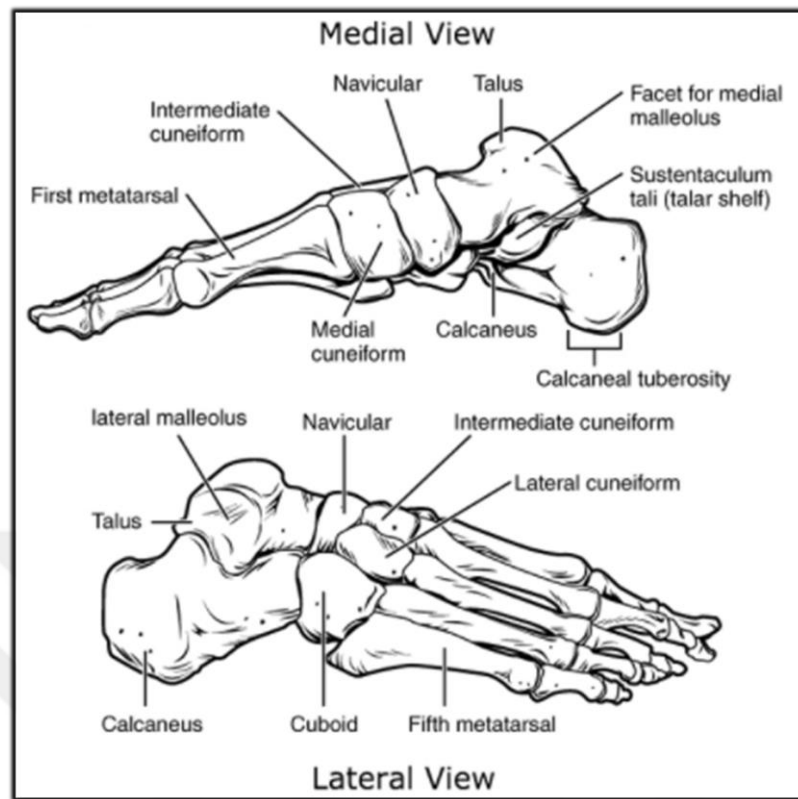


Figure 2.3. Foot anatomy lateral and medial view [32]

### Calcaneus

The calcaneus is generally named as the heel bone and largest bone and along with talus, it forms the area of the foot known as the hindfoot. There are 3 convexities (posterior, anterior, middle facet) on the upper side of the calcaneus that permit the talus to sit on calcaneus top, forming the subtalar joint. Additionally, calcaneus links to the cuboid bone to compose the calcaneal cuboid joint and superiorly articulates with anterior, middle, and posterior facets of talus. Each facet is covered synovial joint with the middle and anterior facets. Among the posterior-middle facets, calcaneal sulcus runs postero-medially and composes the sinus tarsi level [25, 26]. Calcaneus articulates with the cuboid anteriorly and resists the weight-bearing stress, and almost fifty percent of our body weight is borne on the subtalar joints and calcaneus. In the absence of a replacement gait, it usually splits evenly between two feet (weight-bearing). Traction trabeculae radiate from the inferior cortex on radiographs, whereas compression trabeculae radiate from the posterior-anterior subtalar aspects, forming the neutral triangle, a small region with few trabeculae. Both the talus and the calcaneus have structural similarities and differences. Although articular cartilage makes

up more than 60 percent of the talar surface, the calcaneus is made up of just 25 percent cartilage. Calcaneus and talus have extensive ligamentous and capsular attachments. Each is in the main comprised of cancellous bone; nevertheless, talus is much denser. Calcaneus has several, the most vital of which is the triceps surae and its associated AT. Calf muscles exert a lot of dynamic strain on the mechanics of hindfoot. Talus serves as a connecting rod, transporting weights from lower leg and foot to upper leg and foot. Talus helps ankle, subtalar joint, and talonavicular joint function normally. Calcaneus, on the other hand, is subjected to axial stresses applied by the talus or ground reaction forces on a regular basis. During functional operations, each structure is subjected to significant compression and torsional pressures. As a result, hindfoot injuries have a high risk of compromising hindfoot function [12, 20–22, 26].

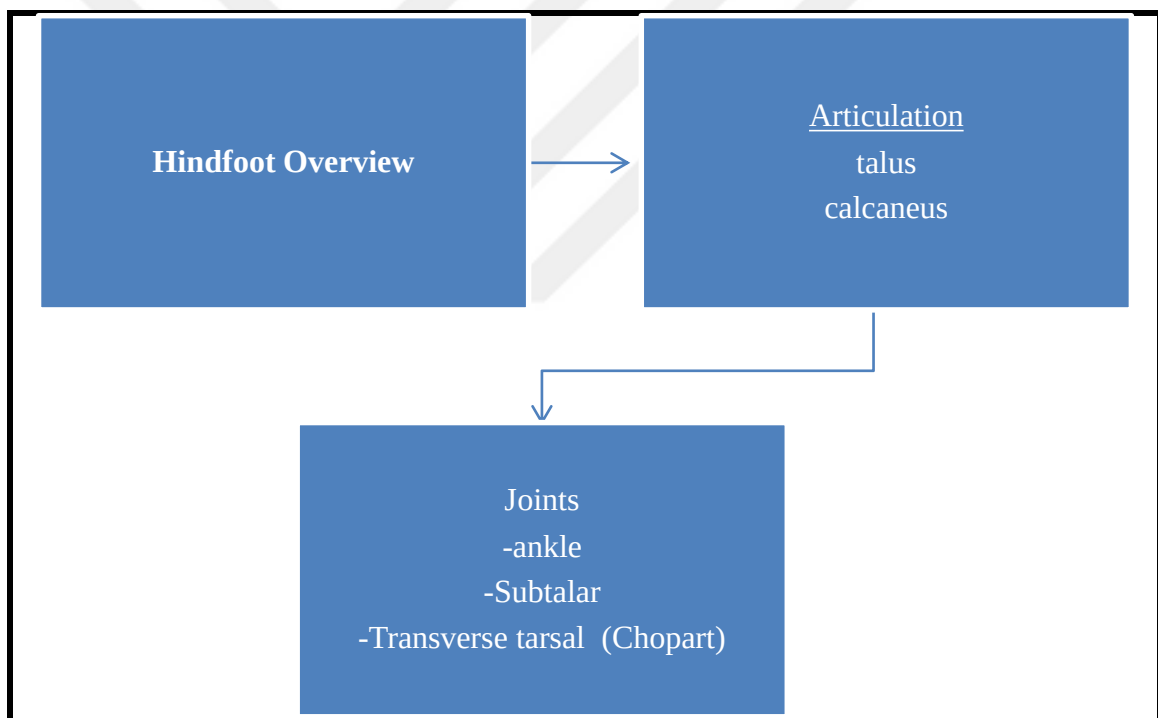


Figure 2.4. Overview of the hindfoot

### 2.1.2. Joints

The Hindfoot begins at the ankle joint and terminates at the transverse tarsal joint (talonavicular & calcaneal-cuboid). The hindfoot connects the mid foot to the ankle at the transverse tarsal joint [21, 22] .

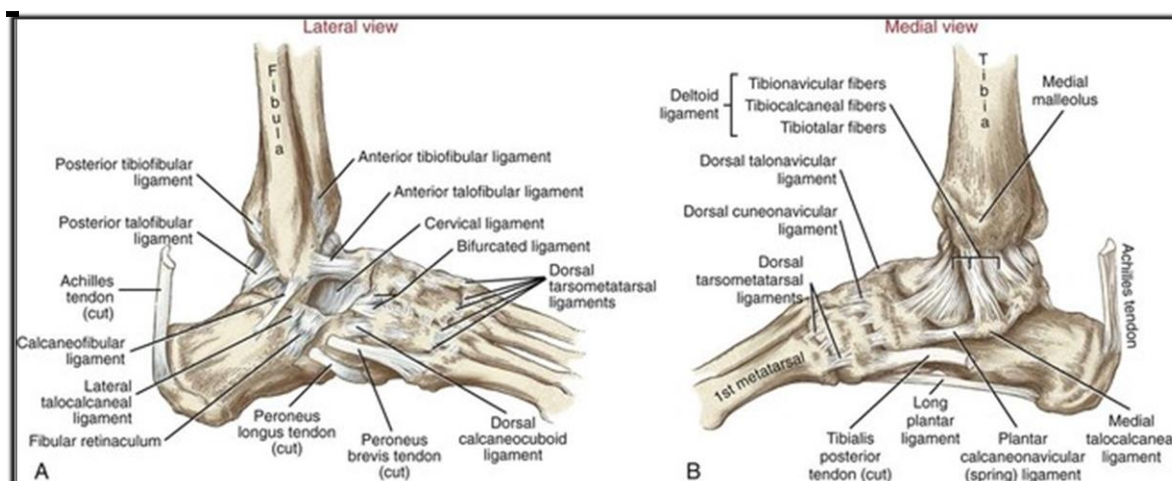


Figure 2.4. Overview of the hindfoot joints [27]

### Ankle (Tibiotalar) Joint

Ankle joint, also named as joint of talocrural, is a synovial hinge joint (uniaxial) that connects the talus to the tibia and fibula, two lower leg bones. Between tibia and its medial malleolus, fibula's lateral malleolus, and talus's trochlear surface, there are three articulations. Hyaline cartilage covers all of the articular surfaces of ankle joint. Joint capsule is rather weak and narrow, although strong collateral ligaments support it medially and laterally. Because of its significant load-bearing nature and great mobility, the ankle joint must be stabilized [22, 27]. The ankle joint is stabilized by medial (MCL) and lateral (LCL) collateral ligaments. Lateral portion of the ankle joint is reinforced by the LCL, a powerful compound ligament. The MCL is a strong triangular band that supports medial facet of ankle joint's. The MCL is necessary to keep the ankle joint stable in eversion and avoid dislocations. The apex and margins of the medial malleolus have a proximal connection. The ligament then extends and inserts itself between the talus, calcaneus, and navicular bones. MCL is made up of three to six sections that range from superficial to deep. The ankle joint's primary role is to facilitate DF and plantar flexion (PF) along the transverse (medial-lateral) axis, which travels via talus in the sagittal plane, as well as some pro-supination via the subtalar and midtarsal joints. In addition, when the heel impacts the ground during the earliest phases of walking, the joint works as a shock absorber [20, 22, 28].

Table 2.2. Overview of the ankle joints

|                                         |                                                                                                                                                                           |
|-----------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Ankle<br/>(Tibiotalar)<br/>Joint</b> | <b><u>Articular surfaces</u></b><br>Tibiotarsal joint: tibia distal end and medial malleolus, lateral malleolus of fibula, talar body                                     |
|                                         | <b><u>Ligaments</u></b><br>Anterior-posterior talo-fibular, calcaneo-fibular, deltoid (tibio-calcaneal, tibio-navicular, tibio-talar parts), fibular collateral ligaments |
|                                         | <b><u>Movements</u></b><br>Dorsiflexion, plantar flexion                                                                                                                  |

### Subtalar Joint

Subtalar joint is created by the talus resting on calcaneus, somewhat displaced laterally against the 5th metatarsal/small toe. This lateral location allows for more inversion/eversion flexibility. Talonavicular and calcaneocuboid joint, both towards the front of the talus, move the subtalar joint [22, 29].

#### *Kinematics*

The subtalar joint's axis is 42 degrees superior to sagittal plane and 16 to 23 degrees medial to the transverse plane. Primary subtalar motion ranges are 5 to 65 degrees, according to the literature. Pronation has a 5 degree ROM, while supination has a 20° ROM. The inversion and eversion ROMs are 30 and 18 degree, respectively. Inversion and eversion total motion has a 2:1 and 3:2 inversion-to-eversion motion ratio, correspondingly [29, 30].

Table 2.3. Overview of the subtalar joint

|                |                                                                                                                                                                                                                                        |
|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Subtalar Joint | <p><b><u>Three facets</u></b></p> <p>1) <i>posterior facet</i></p> <p>2) <i>middle facet</i><br/>(located medially - sustentaculum of the calcaneus)</p> <p>3) <i>anterior facet</i><br/>(continuous with the talonavicular joint)</p> |
|                | <p><b><u>Motion</u></b></p> <p>- inversion/eversion</p> <p>-no role in plantar &amp; dorsiflexion</p>                                                                                                                                  |

### **Transverse tarsal (chopart) joint**

Chopart joint is also named as the mid-tarsal joint. It joins the hind to midfoot. It is constituted of the calcaneocuboid & talonavicular. Midtarsal joint complex supplies both midfoot stability and flexibility, critical to normal gait. Chopart joint ligaments anchorage contain bifurcate, dorsal calcaneocuboid & talonavicular, long & short plantar and spring ligaments [20, 31, 32].

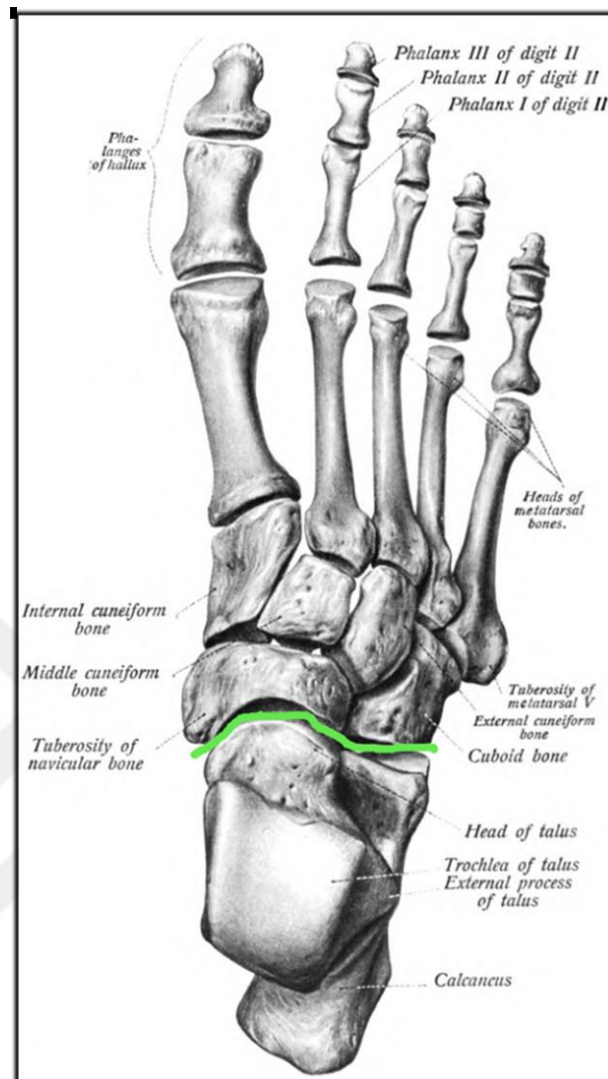


Figure 2.5. Transverse tarsal (chopart) joint [39]

### *Kinematics*

Despite their apparent roles, the talocalcaneonavicular and calcaneo-cuboid joints are treated as a single unit. Talus and navicular make up the foot's proximal, flexible medial column, while the calcaneus and cuboid make up the proximal, more stiff lateral column. With inversion and eversion, while the forefoot stays fixed, the Chopart joint permits the hindfoot to pivot. During the gait push-off phase, it locks in the inversion of the heel and stabilizes the midfoot [33, 34].

Table 2.3. Overview of the transverse tarsal joint

|                                          |                                                                              |
|------------------------------------------|------------------------------------------------------------------------------|
| <b>Transverse tarsal joint (Chopart)</b> | <b><u>Components</u></b>                                                     |
|                                          | -talonavicular joint<br>-calcaneocuboid joint                                |
|                                          | <b><u>Motion</u></b>                                                         |
|                                          | - inversion/eversion of subtalar joint locks & unlock transvers tarsal joint |
|                                          | <b><u>Function</u></b>                                                       |
|                                          | -determine foot flexibility during walking with through subtalar joint       |

### 2.1.3. Embryology

The appendicular skeleton develops as ventro-lateral swellings of mesenchymal cells contained in ectoderm between 4th and 8th weeks of pregnancy, developing to limb buds rather than fetal extremities. Even as the ectoderm gives rise to the skin, mesenchymal cells grow into the ligaments, tendons, muscles and skeleton. Foot appears at around 4.5 weeks and develops in a anterior to posterior, proximal to distal, and dorsal to ventral orientation. By week nine, ossification centers have formed and will continue to grow throughout the pregnancy. Some of the bones in the feet are cartilaginous at birth and ossify during development [35, 36].

### 2.1.4. Vascular Supply and Lymphatics

The foot is perfused by the anterior- posterior tibial arteries. Anterior tibial arter divides into dorsalis pedis and the lateral tarsal arter over dorsal/medial region of the foot. These veins also provide perfusion to the dorsal foot. These arteries merge distally to form the arcuate artery, which runs transversely. Calcaneus has a lot of blood flow. Talus, on the other hand, has a shaky vascular supply [37, 38].

The talus is 60 percent coated in hyaline cartilage and has no muscle or tendon attachments. Despite arterial contributions from three arteries, it is prone to avascular necrosis due to its unique structure. The body is supplied by posterior tibial artery, whereas the superior portion

of head and neck is supplied via anterior tibial artery. The branches of the posterior tibial, anterior tibial, and perforating peroneal arteries supply talar body perfusion. The posterior tibial artery is detectable in proximal tarsal tunnel region, behind medial malleolus. Before creating the medial-lateral plantar arteries, it marches anteriorly via medial portion of ankle and the plantar hindfoot, giving off the artery of tarsal canal. Perforating peroneal and posterior tibial vessels runs behind the talar neck, forming an arterial anastomosis. The principal perfusion for the talar body is provided by this arterial, artery of tarsal canal [37, 39]. Tarsal canal artery comes around posterior tibial artery approximately one centimeter proximal to medial-lateral plantar arteries. Central and lateral two-thirds of the talar body are supplied by tarsal sinus artery, which anastomoses with artery of tarsal sinus and gives out the deltoid branches that provide remaining talus. The transversely flowing deep plantar arch anastomoses the medial and lateral plantar arteries distally. Toes are perfused by terminal branches of the arcuate and deep plantar arches. Posterio-lateral ankle and hindfoot are served by the fibular or peroneal artery. Collateral circulation is supported by connecting arteries or anastomosis between the branches of fibular, anterior tibial and posterior tibial arteries [46, 47] .

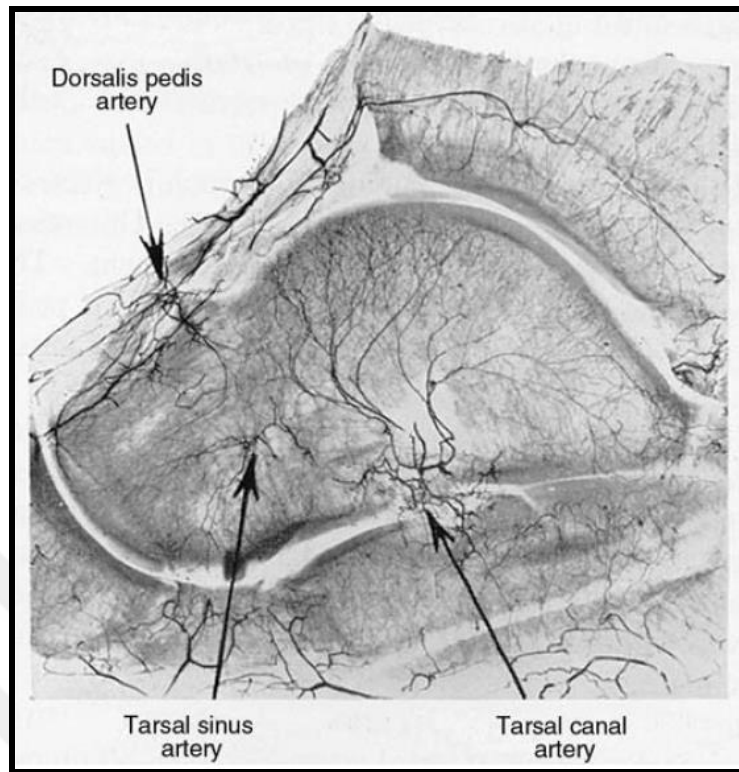


Figure 2.5. Vascular supply to the talar body [46]

#### 2.1.5. Skin, Subcutaneous and Fascia

The skin comprises of layers named hypodermis, epidermis and dermis. Epidermis is the outmost layer, and the hypodermis is the innermost layer (under the dermis) which is a fatty layer with variable thickness. Subcutaneous tissue also called as superficial fascia, hypodermis, subcutis, and tela subcutanea is the deepest skin layer that lies nearest to the muscle. Fat forms a layer that isolates the body from cold and assist to absorb shock and prevent to damage to the internal organs [40]. Furthermore, it gives the skin structural stability. The hindfoot's skin and subcutaneous tissues are very thin. The heel pad is a one-of-a-kind structure on the backfoot. Its biomechanical properties are unmatched by any other tissue. During walking and running, heel pad must be capable of withstanding significant compression and shear pressures. The honeycomb-like structure of fibroelastic septae around encapsulated cell fatty lobules is the source of its load-absorbing properties. Crushing damage or avulsion from calcaneus plantar surface can cause heel pad injury [40–42].

The fascia is the next anatomic layer, and terminology used by surgeons and anatomists in the literature is the most confused and ambiguous. Anatomists split the fascia into deep and

superficial layers. Others define superficial fascia as a connective and vascular tissue distinct fibroareolar layer [43, 44].

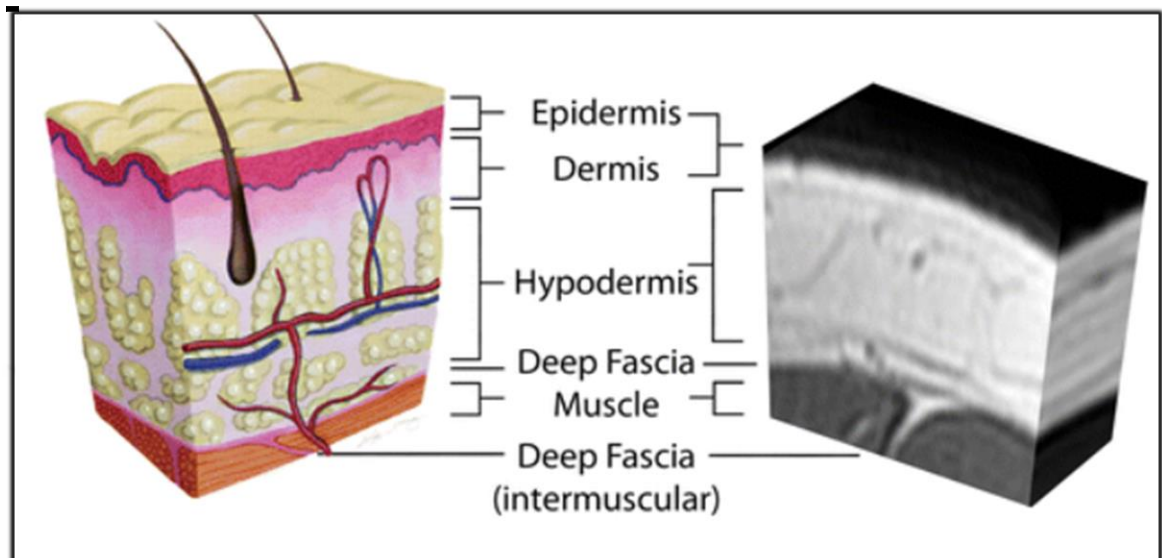


Figure 2.6. Soft-tissue layers [52]

## Plantar fascia

### Anatomy

Plantar fascia (PFa), also called as plantar aponeurosis, is a powerful collagenous structure that extends almost the entire length of the plantar aspect, from the os calcis to the complicated insertion at the metatarsal heads. It is comprised of densely concentrated collagen fibers. Typically, these fibers are aligned in a longitudinal orientation, even though some of them run in an oblique transverse direction. The longitudinal arch is supported by these many bands. Plantar ligaments, both short and long, are found in other ligaments. Short plantar ligament inserts into the navicular underside from a more distal position on the os calcis undersurface. Long plantar ligament wraps around the os calcis and enters into the second to fifth metatarsals' bases. Long plantar ligament is separated from the PFa by many folds of muscles and tendons. Quadratus plantae, which enters into the FHL, is the deepest. The bellies of three key muscles are the most visible. Flexor digitorum brevis lies in the middle, with abductor digiti minimi laterally and abductor hallucis medially on either side [43, 45, 46]. These muscles are covered by the PFa. Three bands with non-distinct

boundaries make up its structure: a medial, central, and lateral band. Muscle of the fifth digit and hallux is covered by medial and lateral bands. The medial and lateral bands are narrow in comparison to the thick central band that encompasses the short and long digital flexor muscles. Central band has the strongest tensile strength of the three bands and is the one that is most commonly affected by illness. It separates into five branches distally from the os calcis medial tubercle. Fascia is innervated by posterior tibial nerve's two branches. Medial calcaneal nerve, the most superficial, runs parallel to the posterior tibial nerve. Lateral plantar nerve's first branch goes out the lateral plantar nerve, which is the more essential (deeper) branch. Posterior tibial nerve's prior considerable portion is lateral plantar nerve [45, 46].

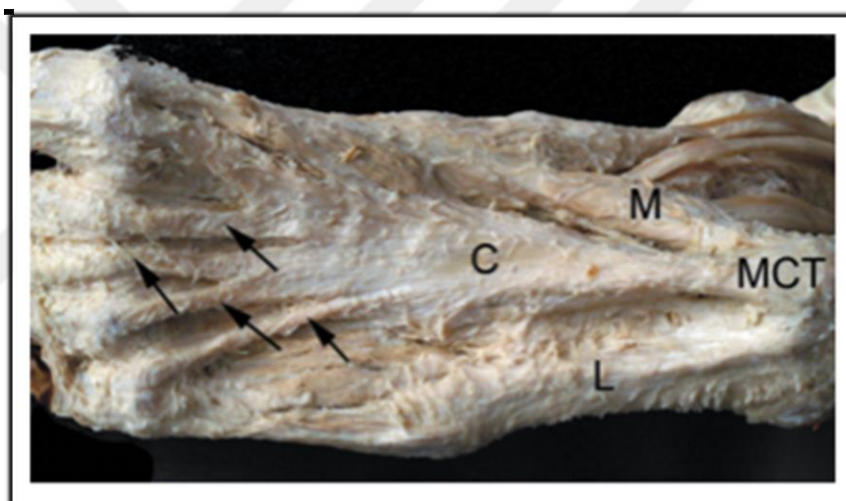


Figure 2.7. Plantar aponeurosis parts (central (C), medial (M) and lateral (L), medial calcaneal tubercle (MCT) [53]

### Biomechanics and Pathophysiology

PFa has been studied quite well regards to biomechanical perspective. It has a main role in foot biomechanics, in supporting the longitudinal arches as a stabilizer. The PFa provides this its key role in propulsion mechanisms, dissipating the forces and stresses during gait or other loading situations [47, 48]. According to this, it helps to remain the MLA and transmit forces from hind to forefoot [55, 57]. Supination during propulsion is aided via intrinsic muscular system contractions and by the plantar aponeurosis. With digituses DF, arch is raised and reinforced by the PFa that causes to a more fix foot over the gait cycle. This action

mechanism was defined by Hicks, and it was named as the Windlass Mechanism [47]. The toes are stretched or dorsiflexed, and the plantar aponeurosis is pulled around the metatarsal heads, according to this process. A cable being coiled into a windlass was used to describe this process. Because of this, PFa's pull, the hindfoot supinates, reducing the space between the calcaneus and metatarsal heads. Furthermore, because DF of the toes is pressed by advancing momentum during walking and arch height is increased, this activity is achieved without any direct muscular engagement. Serrafian describes the foot as having the structural components of a beam-truss. When beam's plantar surface is stressed, the skeletal structure of the foot acts as a truss, allowing the tensile forces on the plantar surface of the beam to be relieved. Following that, the foot is only vulnerable to compressive pressures. This mechanism is crucial during the propulsive phase of the gait cycle, when foot must operate as a firm lever. [47, 49].

PFa is also able to store energy and convert into propulsive force, behave such an elastic tissue [49, 50]. In contrast, because all of its type 1 collagen fibers are oriented in a longitudinal manner, it has been thought of as an aponeurosis. Nothing is known regarding its elastic fiber composition, extracellular matrix characteristics, or innervation [45, 46]. In recent studies, it was indicated that older had a more proximally inserted AT than younger people. According to these results indicate that, from a morphological perspective, connection between the AT and PFa is more likely in younger individuals [51, 52].

Walking is the most stressful activity for the PFa. Towards heel strike, the ligament is relaxed, and at the end of the toe-off phase, it is maximum tightened. Ligament microtears are caused by repeated trauma. Once there is a sudden high-energy beat or foreign body penetration, more explicit tears may ensue. Plantar fasciosis is the name given to PFa Micro-tears. When they become noticeable and patients develop symptoms, the name PFs is used, even though, as with other tendon and ligament illnesses, plantar fasciopathy is a better description. This suggested nomenclature better reflects the underlying histology, which includes inflammatory cells only in rare cases. Other conditions include PFa rupture due to trauma and plantar fibromatosis [53]. Plantar fibromatosis is a very visible entity that develops as a result of plantar fasciopathy and trauma. Even though calcaneal attachment growth is prevalent, plantar fibromatosis usually affects the distal two-thirds of the ligament. The thickness of the PFa is usually measured sonographically, and it is shown to be higher in individuals with PFs and diabetes [54, 55]. In addition to this, the thickness of the PFa diversify inside a single person and at a location where measurements aren't usually taken

obviously determined. Considerably, from a clinical point of the view, PFa extent as to have presence of thickness is regarded to be a good predictor of type I diabetic problems. [56]. In diabetics, thickening of the PFa & AT may enhance foot ulcers due to the foot biomechanics alteration such changes a cavus foot, i.e. [57].

#### **2.1.6. Nerves**

Foot innervation is provided by the branches of the saphenous, superficial-deep fibular, medial-lateral plantar, and calcaneal nerves. The saphenous, a branch of the femoral nerve that may occasionally be injured meantime AT repair, sends sensations to the medial ankle and foot, resulting in discomfort and a burning sensation in the medial hindfoot [58].

At knee, the superficial -deep roots of main fibular nerve separate. The superficial fibular nerve, main fibular nerve branch, supplies feeling to the bulk of the dorsal foot. The deep fibular nerve supplies sensation to the first web space and innervates the extensor digitorum brevis and extensor hallucis brevis muscles [59]. Tibial nerve branches out the medial- lateral plantar at ankle level medially (tarsal tunnel). Medial plantar provides sense to first through third digits plantar side and fourth digit medial side. In addition to, it supplies motor innervation to abductor hallucis brevis, flexor digitorum brevis, flexor hallucis brevis, and first lumbrical. Lateral plantar arm provides sense to the 4th digit lateral plantar portion and whole 5th digit plantar portion. Also, it supplies motor innervation to the quadratus plantae, abductor and flexor digiti minimi [58, 59]. The tibial and common fibular nerves, which transmit sensation to the lateral hind-midfoot, create the sural nerve, which is normal. Both the tibial and sural nerves have calcaneal branches that supply innervation to the heel [58–60].

#### **2.1.7. Muscles**

The muscles responsible for foot motion can classify as extrinsic and intrinsic according to their location. The foot incorporate several intrinsic muscles which originate in the foot-, that are responsible for toe movements, arch reinforcement and protection upright posture. The extrinsic muscles categorize into lateral, anterior and posterior compartments. Intrinsic muscles subdivide into two classification; plantar and dorsal. Additionally, plantar muscles further fall into three layers [61](Table 2.4).

Table 2.4. Foot Muscles

| <b>Extrinsic</b>                                                              |                                                                                              |                                                                             |                                                                                                  |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Anterior                                                                      | Posterior                                                                                    |                                                                             | Lateral                                                                                          |
| Anterior tibialis<br>Extensor hallucis & digitorum longus<br>Peroneus tertius | <i>Superficial</i><br><br>Gastrocnemius<br>Soleus<br>Plantaris                               | <i>Deep</i><br><br>Posterior tibialis<br>Flexor hallucis & digitorum longus | Peroneus longus & brevis                                                                         |
| <b>Intrinsic</b>                                                              |                                                                                              |                                                                             |                                                                                                  |
| Dorsal                                                                        | Plantar                                                                                      |                                                                             |                                                                                                  |
| Extensor digitorum & hallucis brevis<br>Dorsal interossei                     | <i>First Layer</i><br>Abductor hallucis<br>Flexor digitorum brevis<br>Abductor digiti minimi | <i>Second Layer</i><br>Quadratus plantae<br>Lumbricals                      | <i>Third Layer</i><br>Flexor hallucis brevis<br>Adductor hallucis<br>Flexor digiti minimi brevis |

ones of these, the flexor digitorum brevis, abductor hallucis and digiti minimi are placed in region of the hindfoot. Its ligaments and tendons band together the hind parts of the foot to other parts (as is the case with the AT), assist motion, and partake to balance and stability [61].

### 2.1.8. Function

Hindfoot's structure is necessary for the whole foot function. Furthermore, hindfoot's health and biomechanics provide to control gait and may contribute to FP and many of the joints above [12].

The functions of the hindfoot is specially important element of gait mechanics inasmuch as during normal gait or running, it is the primary body part that contacts the ground though there is debate about whether hindfoot strikes, rather than forefoot and midfoot strikes, are the best movement pattern. The hindfoot bear and distribute weight to the foot as standing transfer the external forces from the ground to the lower limb and to allow complex foot movements in coordination with the ankle joint, in particular inversion, eversion and axial rotation [62].

The rotation along the proximal segment's medio-lateral axis is DF-PF, the rotation about the distal segment's vertical axis is adduction-abduction, and the rotation about the axis orthogonal to the preceding two axes is eversion-inversion. In terms of clinical terms, eversion and inversion are identical to pronation and supination. At the end of the stance phase, the midfoot plantarflexed, inverted, and adducted with regard to the calcaneus, reversing these rotations [63, 64].

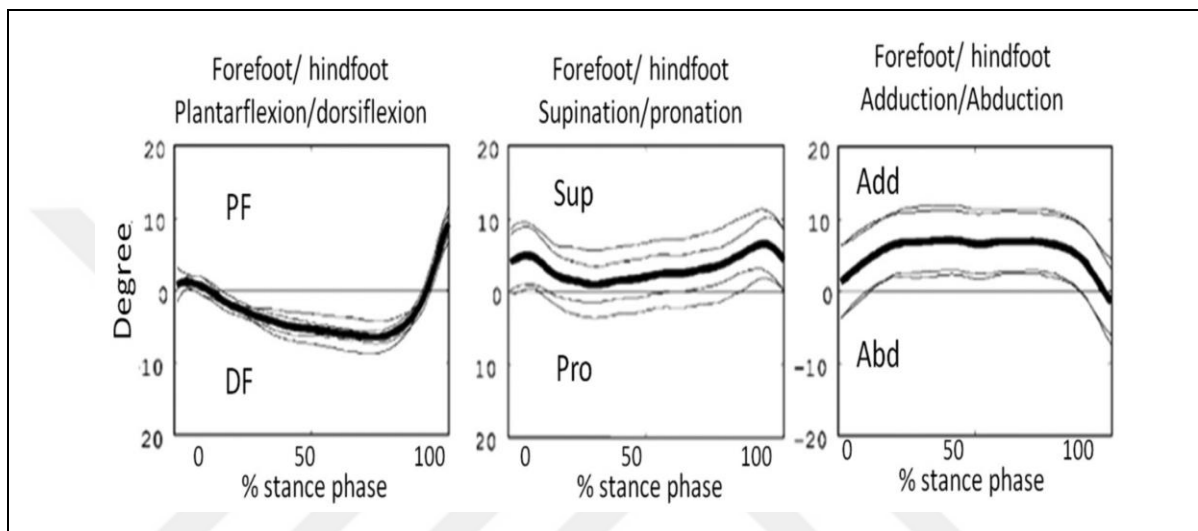


Figure 2.8. The kinematics of the forefoot according to the hindfoot [72]

(Add, adduction; Abd, abduction; PF, plantar flexion; DF, dorsiflexion; Sup, supination; Pro, pronation).

Regarding the midfoot-metatarsal ROM, it is limited as well in 3 planes. At this level, a crossing from late stance supination to 10 degree of pronation at the end of the stance is remarked. The windlass mechanism between hind and forefoot is described by calcaneus movement linked to the metatarsus. At the three planes, an alignment of the calcaneus-metatarsus may be seen in mid-stance when the influence of the body weight tends to flatten the arch [65]. In addition, the degree of inversion and eversion, as well as the supination and pronation of the calcaneus equivalence with regard to the metatarsus, might be used to objectively measure lamina pedis twist. The substantial PF of the metatarsus is paired with a significant DF given by the windlass mechanism at the conclusion of stance phase. The forefoot kinematics in relation to the hindfoot are consistent with Hicks' arch rising process, providing for a better understanding of foot adaptation during locomotion [47, 63].

Leg rotation produces an identical tibiofibulo-talar unit axial rotation, with its 3 components rotating in the same direction. In the position of standing plantigrade, leg external rotation is

a talo-tibiofibular unit rotation and for the talus to externally rotate, the CPU must internal rotation, PF and supination. PF can be come up through the subtalar joint with synchronical In compensating, the PF or ankle might DF, keeping the leg vertically aligned. In other words, with respect to the talo-tibiofibular unit, the CPU is in varus. If the movement continues, the CPU will deform in torsion, resulting in forefoot pronation [63, 66]. Hindfoot varus, with regard to the forefoot pronation, comes up with a cavo-varus deformity, by way of an increase in medial arch heigh. Tibia external rotation thereby produces a classic cavo-varus deformity while internal tibial rotation with descendent hindfoot valgus, forefoot supination and flattened medial arch produces a classic planovalgus deformity. Excessive ever-inversion motions can bring down the stability of the ankle, and also affect ankle joint moments. One of the most controversial issue of the recent studies has been whether the limited motions of hindfoot motion are more effective to decrease potential of injury risk [25, 64].

## **2.2. HINDFOOT PAIN**

The hindfoot is foot part which is proximal to the midtarsal joint. Explicit reasons of pain are not thought (post-traumatic injuries, sprains, fractures, cutaneous lesions.e.g.)[10] . In General, the most frequent reason is in consequence of the action or mechanical agents. The plantar bone (talus and calcaneus), is enclosed by soft structures that function as shock absorbers of direct or indirect agents that cause traumas [10, 28]. A very strong event with a stiff object can give rise to traumas either in the bone structure, soft muscular, articular and ligamentous parts. In a similar way, the overload of the heel by overweight, very tight footwear usage or a constant friction are also agents that produce pain in the hindfoot as well as high intensity sports, with sequenced injuries in the same area can cause traumas. The major etiologies on the subject are consecutively exposed by following the pain localization [75]. Structures that may have pain locations include:

Table 2.5. Structures and sites of pain [75,76]

| Pain Sites                                       | Common sources of pain                                                                                      | Less common pain sources                                                                                            |
|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| <b>Posterior</b>                                 | AT insertion<br>Superficial calcaneal bursa<br>Posterior impingement of soft-tissues<br>Calcaneal apophysis | Sural nerve                                                                                                         |
| <b>Inferior</b>                                  | Plantar fascia<br>Calcaneal fat pad                                                                         | Medial-lateral calcaneal nerve                                                                                      |
| <b>Medial</b>                                    | Tibialis posterior tendon & sheath<br>Tibialis posterior insertion & apophysis                              | FHL & sheath<br>Abductor hallucis<br>Deltoid & spring ligaments<br>Posterior tibial nerve<br>Bone: medial malleolus |
| <b>Lateral</b>                                   | Ankle lateral ligaments<br>Sinus tarsi                                                                      | Peroneal tendinopathy<br>Cubometatarsal joint<br>Peroneus brevis insertion                                          |
| <b>Deep vague pain</b>                           | Subtalar joint                                                                                              | Bone (calcaneus, talus, navicular) pain                                                                             |
| FHL, flexor hallucis longus, AT, Achilles Tendon |                                                                                                             |                                                                                                                     |

Hindfoot sensations occur beneath the ankle and are sometimes mistaken for ankle discomfort. Flat feet and soreness are caused by issues such as posterior tibial tendon insufficiency. On the inside or outside of hindfoot, pain might occur. This also causes symptoms of weakness and instability around the ankle and hindfoot. Stress fractures, ankle instability, and peroneal tendonitis can all be caused by having a high-arch foot. Arthritis

can also affect the hindfoot, causing dull discomfort, stiffness, and deformity later on. Swelling or edema in the hindfoot area may indicate an inflammatory or joint soft tissue processes. When the pressure is applied to the bone or structure, it excites intense pain [8, 67].

The pathologies that present with HP are presented according to the affected structures [11, 68]:

Table 2.6. Hindfoot pain pathologies

| <b>Chronic Conditions</b>                  | <b>Overuse tendon conditions</b> | <b>Traumatic Conditions</b>          | <b>Medical conditions</b>  |
|--------------------------------------------|----------------------------------|--------------------------------------|----------------------------|
| Plantar fasciitis                          | Peroneal tendon injury           | Anterior&posterior ankle impingement | Rheumatologic disease      |
| Tarsal tunnel syndrome                     | Posterior tibial tendinopathy    | Heel contusion                       | Paget disease              |
| Achilles tendon inserion&hallung deformity | Flexor hallucisi tendinopathy    | Calcaneal & talar stress fractures   | Osteomyelitis of calcaneus |
| Sinüs tarsi syndrome                       |                                  |                                      | Sickle cell disease        |
| Piezogenic papules                         |                                  |                                      | gout                       |
| Subtalar arthritis                         |                                  |                                      | Metastatic disease         |

### 2.3. DIAGNOSTIC IMAGING

Diagnostic imaging can help to understand the injury and facilitate the surgical planning. While a clinical examination may reveal a diagnosis of HP, imaging is required to detect degree of the damage and uncover concomitant diseases. Severe HP often show complex pathologic situation that can be optimally characterised with specialized studies like computed tomography (CT) and magnetic resonance imaging (MRI) [67, 69].

### 2.4. ASSOCIATED CONDITIONS

HP can be resulted from a diversity of disorders which commonly include overpronation & supination and varus & valgus, haglund's deformity, retrocalcaneal bursitis, calcaneal stress

fractures, heel fat pad atrophy, tarsal tunnel syndrome, PFs, Achilles tendinopathy. These hindfoot pathologies result in pain of the calcaneal bone, and hindering patients' gait [10, 67].

#### **2.4.1. Overpronation & Supination and Varus & Valgus**

Overpronation implies to foot inward roll often connected with flat feet, and supination refers to foot outward roll. Both overpronation and supination may present ligaments, tendons, joints and bones stress in the hindfoot area as well as in other parts of the foot and the leg [70]. They are common congenital anomalies that appear in childhood and are frequently recognized by a person's gait. During weight-bearing, these variances cause the foot to invert/evert / "tilt" inward or outward at the ankle. Pregnancy, obesity, and repeated activities like jogging can all contribute to overpronation and flat feet. Overpronation and supination can lead pain in the back, hips, legs, knees, and feet, though they are rarely significant [70, 71].

Varus and valgus are used to determine permanent hindfoot angular abnormalities without taking forefoot position into account. All bones and joints can be aligned in the frontal or coronal planes using these terminology. Genu varus or valgus, cubitus varus or valgus, hallux varus or valgus, and varus or valgus malunion following a bone fracture are all examples of varus or valgus malunion. Varus and valgus are the identical alignment positions in the subtalar joint that result from inversion and eversion abnormalities. Varus-valgus begins as adaptable and so flexible early in any foot pathology, but eventually becomes static and inflexible as the underlying pathology improves and the underlying pathology persists. In the majority of circumstances, the words varus and inverted, as well as valgus and everted, are interchangeable. There are isolated varus or valgus abnormalities of the hindfoot with no inver-eversion in rare cases. These can be noticed in certain deformities and post-traumatic circumstances [72, 73].

#### **2.4.2. Haglund's deformity**

Haglund's deformity is a discomfort and swelling in the posterior heel caused by an osseous protrusion of the postero-superior calcaneus area. The etiology of the malformation is unknown, however various theories have been proposed. (For example, a tight AT, changed joint biomechanics, a high arch, genetics, and tight or poor-fitting shoes). Climbing stairs or

moving frequently and then continuing to walk after a period of rest aggravates the pain in the posterior area of the heel. It is possible for this malformation to be unilateral or bilateral. On X-ray and MRI, a tuber may be seen on the posterior side of the heel, and a bony protrusion can be seen in the postero-superior region of the calcaneal tuberosity. Recent studies indicated that 25 percent of ATpathy patients have Haglund's deformity [11, 74].

#### **2.4.3. Retrocalcaneal bursitis**

Retrocalcaneal bursitis is the most widespread kind of heel bursitis, characterized by shoe discomfort and severe inflammation. Between antero-inferior wall of the AT and the postero-superior calcaneus portion is the retrocalcaneal bursa. The anterior retrocalcaneal bursa is made up of fibrocartilage, with adipose tissue in the upper section and a posterior surface that connects to the anterior AT paratenon. Retrocalcaneal bursitis is caused by retrocalcaneal bursa irritation, ill-fitting shoes or misuse of the heel or ankle. Haglund's deformity, rheumatoid arthritis, psoriatic arthritis, ankylosing spondylitis, Reiter's disease, pseudogout, and gout are all common complications. As a result, it's critical to assess the coexistence of various conditions in people who are impacted. Anterior AT discomfort and posterior ankle pain with medial and lateral compression are among the clinical characteristics. Swelling or erythema around the AT may also improve [11, 75].

#### **2.4.4. Calcaneal stress fracture**

Calcaneal stress fractures take place as a result of repeated heel striking and are particularly common among runners. Patients usually present with discomfort comparable to that of PFs, although sensitivity on medial and lateral sides of calcaneal bone is often present. Imaging modalities like as X-rays or MRI can confirm the diagnosis of a calcaneal stress fracture when it is suspected clinically [11, 76].

#### **2.4.5. Heel fat pad atrophy**

Fat chambers are twisted round by elastin fibers, and stiff circular or collagenous septa make up the heel pad. The fat pad in the heel absorbs shock and serves as a cushion. Nonetheless, atrophic alterations occur as people age. The second most common cause of PHP is fat pad atrophy in the heel. It is responsible for 14.8 percent of all instances of PHP. It is also caused

by rheumatoid arthritis or a change in biomechanical alignment. When this happens, the fibrous membrane in the heel fat pad is destroyed, moisture is lost, and soft tissue elasticity is diminished, resulting in the heel fat pad's shock absorption capability being reduced [77, 78]. Responsive palpation of the calcaneus bone while pushing the heel with the hand is a clinical feature of heel fat pad atrophy, as is worsening of heel discomfort, especially when standing for long periods of time with bare feet or on a hard surface. Additionally, the plantar portion of the calcaneus bone is sensitive. As a result, using ultrasonography to confirm heel fat pad atrophy can increase diagnostic accuracy [11, 78] .

#### **2.4.6. Tarsal tunnel syndrome**

This syndrome is a painful foot situation resulted from pressure of tibial nerve. It is more widespread in female and is resulted from a number of factors like anatomic-biomechanical abnormalities (hindfoot varus or valgus e.g.), poorly fitting shoes, trauma, hypertrophic retinaculum, systemic inflammatory arthropathies, tarsal coalition, postoperative scarring, lower diabetes, tenosynovitis, osteophytes, perineural fibrosis, and neuroma. Though, there are no specific diagnostic tests, it can be diagnosed with detailed historical assesment and examinations, like Tinel test or two-point discrimination. Patients can have prickly or stinging pain, numbness, or burning in post-medial ankle and heel, as well as discomfort extending to distal toes. Furthermore, toes motor weakness may take place [11, 79].

#### **2.4.7. Plantar fasciitis**

Plantar fasciitis, the most widespread cause of medial PHP, is a chronic degenerative irritation of the PFa origin at medial calcaneal tuberosity as well as surrounding perifascial structures including plantar aponeurosis of foot [80].

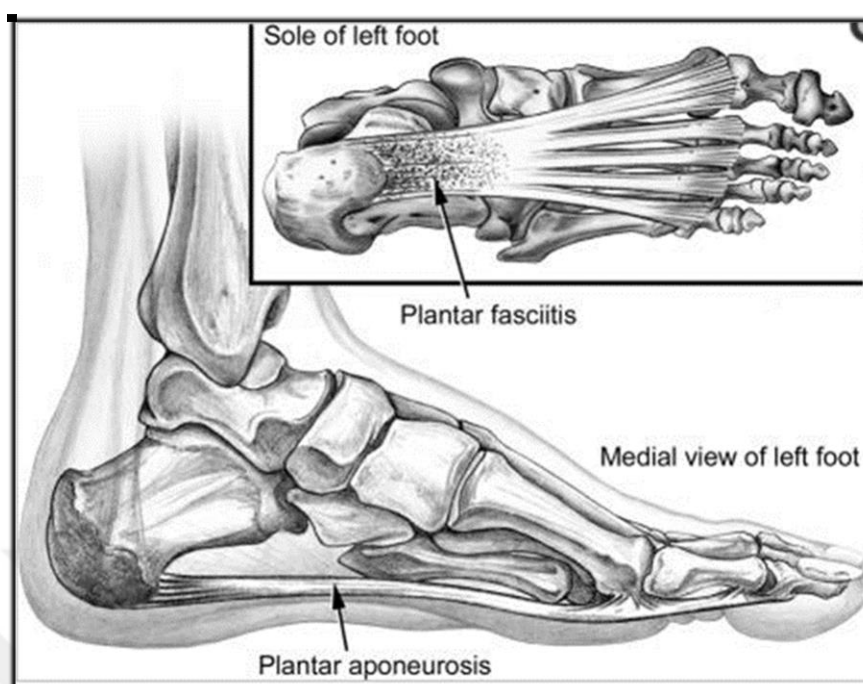


Figure 2.8. Plantar fasciitis [56]

### **Epidemiology**

PFs has approximately one million patient visits per year, with around 60 percent of these to primary cares [81]. Although decisive incidence and prevalence of PFs by age are unclear, estimations show that they affect roughly 10 percent of the general public, with 83 percent of these patients being active working individuals aged 25 to 65 [82]. Additionally, it is common in both athletic and sedentary populations and associated with a diversity of sports but is mostly reported in elite and recreational runners with 5 to 10 percent incidence. Some researches show prevalence rates among in runners to be as high as 22 percent. It can also present in a third of the bilateral cases [80–82].

### **Etiology & pathophysiology**

The PFa originates from the postero-medial calcaneal tuberosity and attaches into each metatarsal head to form the longitudinal arch. This condition is primarily a degenerative process. Histologic samples taken from PFs patients undergoing PFa surgery demonstrates myxoid degeneration with fragmentation, collagen disarray, granulation tissue, micro-tears, bone marrow vascular ectasia, and lack of traditional inflammation [53, 82, 83]. Additionally, ultrasound assesment often finds out calcifications, intrasubstance tears, thickening and PFa heterogeneity. These changes commonly seen on ultrasound, induce a

non-inflammatory condition and dysfunctional vasculature. According to these findings, the condition is a degenerative fasciosis without inflammation, not a fasciitis. That's why, plantar fasciopathy is a more accurate definer. Although the diagnosis including the portio "itis," the condition is clearly characterized by lack of inflammatory cells [53, 83].

### **Risk Factors**

The reason of PFs is multifactorial but most cases are due to overuse stress. It exhibits with sharp localized pain during weight bearing, specially with the first steps in mornings. In some cases, a heel spur may be found, but it is not a causative factor. It often takes place in middle-aged (40 - 60 years) women and is wide in military servicemen, long-distance runners (repetitive strain) and obese people (BMI >27 kg per m<sup>2</sup>). Pes planus, pes cavus, ankle DF limitation (which leads the foot to overpronate), and excessive pronation or supination are all predisposing factors. Pes planus can create significant tension near the PFa's origin [80, 84]. Because the foot cannot effectively evert or absorb trauma, pes cavus can generate undue pressure on the heel. The gastro-soleus and other posterior leg muscles are frequently observed to be tight. Tight muscles can alter typical motion biomechanics. Weight-bearing, age, leg length asymmetry, heel pad atrophy, vocations requiring extended standing, and low-heeled shoes with solid bottoms or tightly fitting shoes are all risk factors [84, 85].

### **Diagnosis & imaging**

Patients will generally present at inferio- medial heel progressive pain. In more severe situations, pain might radiate proximally. The pain is commonly described as severe and worse with the first few steps in the morning by patients. Long durations of standing or sitting will further aggravate the discomfort. Pain usually subsides after ambulation or the start of an athletic activity, but often returns later in the day. It may be replicated in most cases by palpating the plantar medial calcaneal tubercle, as well as passive DF of the toes and foot. The windlass test refers to the passive DF of the first metatarsophalangeal joint (positive) [86, 87]. Secondary, the causative factors may contain a tight AT, pes cavus or planus. That's why, the assesment of a patient's gait may be beneficial. Stress fractures, fat pad contusion or atrophy, and nerve entrapments such as tarsal tunnel syndrome should all be examined in the differential diagnosis of PFs. In most cases, clinical diagnosis and imaging are not required [88]. If there is another indication of the other injuries or patient fails, it may be important for obtaining x-rays or ultrasound evaluation . The American

College of Radiology Guidelines indicate that although radiography is typically not sensitive for PFs, it should be the initial study [89]. Soft tissues calcifications or heel spurs on the inferior surface of the heel may be seen on X-rays or ultrasonic assessment. The PFa may seem thickened and swollen on ultrasound. Ultrasound findings consistent with PFs contain PFa thickness greater than 4.0 mm. Whether the patient does not respond to conservative therapy after longer periods, then it maybe considered MRI to assess for fascial tears, stress fractures, or osteochondral defects. Additionally, MRI can demonstrate increased PFa thickness and signal intensity. For evaluating and distinguishing PFs, ultrasonography is a cost-effective, precise, and dependable alternative to MRI. Plain radiography can detect bone abnormalities, and lateral heel radiographs can reveal a heel spur. Eventhough people with chronic HP are more likely to have a spur, it can remain after symptoms resolve [84, 86, 88].

PFs is difficult to treat and patient unsatisfaction is prevalent with most treatments. Most of cases are managed non-surgically (90 percent) but recurrence of pain is obstruction. An inter-professional approach is necessary because there is no single treatment for everyone. Even when a treatment option works, symptoms frequently last week or months to subside [80, 82, 90].

#### **2.4.8. Achilles Tendinopathy**

Tendinopathy is the degeneration or inability to heal of the tendon as a result of recurrent stress without proper recuperation. The word tendinitis is avoided because of inflammatory activity, thay can or can not be present in the injured area. Inflammation cannot be examined clinically on a regular basis. AT connects to the gastro-soleus superiorly and enters inferiorly into the calcaneus' bottom [91]. ATpathy is a widespread overuse injury resulted from excessive compression or triceps surae mechanical loading. It divides into mid-portion (non-insertional) and insertional tendinopathy. Discomfort at two to six cm from the calcaneal insertion, as well as insertional one pain at the AT insertion, make up the mid-portion. ATpathy is a clinical diagnostic that occurs when a patient has localized discomfort, AT edema, and loss of function. In terms of pain localization, ATpathy injuries are divided into three categories: midportion tendinopathy (55-65 percent of injuries), insertional tendinopathy (20-25 percent), and proximal musculotendinous junction injuries (9-25 percent) [74, 92, 93]. Patients, on the other hand, have discomfort at the insertion and midportion at the same time, with around 30 percent experiencing bilateral pain.

Tendinopathy is also marked by increased tissue thickness (tendinosis), a lack of typical collagen, an increase in proteoglycans, and a general breakdown in tissue structure [91, 92]. In both asymptomatic and symptomatic tendons, these structural alterations increase cross-sectional area, reduce tendon stiffness, and modify viscoelastic properties. Furthermore, tendon alteration (tendinosis) is commonly accompanied by other disorders, such as the spread of intratendinous calcifications, bone abnormalities, and the retrocalcaneal bursa in the insertional one [91, 92] .

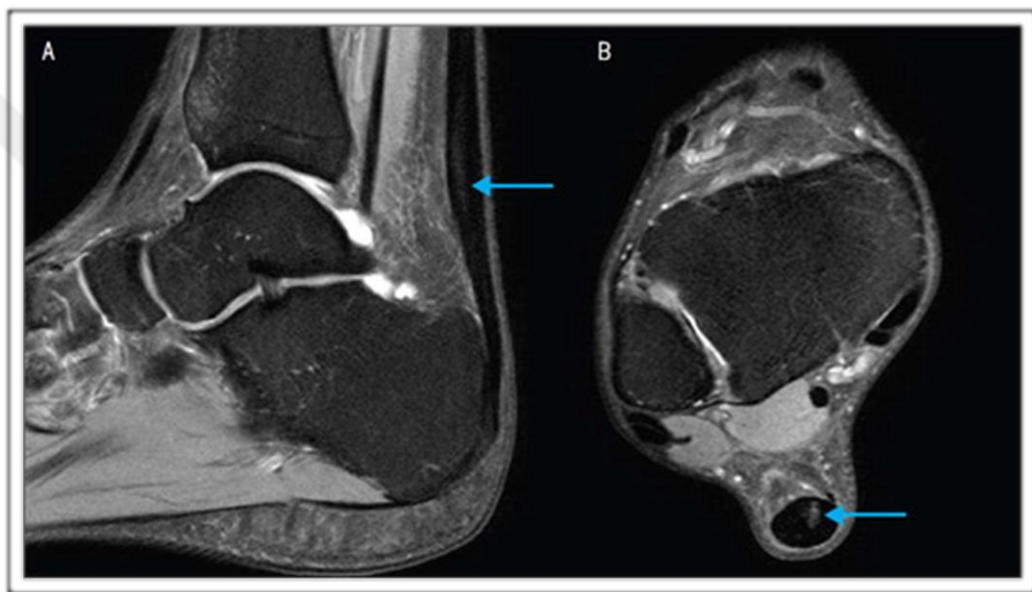


Figure 2.9. Abnormal Achilles tendon magnetic resonance imaging [100]

### **Injury Mechanism**

The AT is mechanoresponsive which can respond to the tissue's loading requirements. Exact reason of tendinopathy diverges, but the most extensive cause in athletes is excessive loading with inadequate recovery time between training performances. Among athletes with ATpathy, (60- 80 percent) detailed a sudden change or increase in training duration or intensity (training-load error). Nevertheless, not all cases are related with sport, and increased work or daily activity can cause to excessive loading. Compression on the AT and calcaneus because of footwear or activities that put the ankle in DF or an anatomical abnormality (Haglund deformity) can contribute to pain development [94–96].

## **Risk factors**

The risk of developing ATpathy is assumed to be multifaceted, with intrinsic and extrinsic variables all contributing to either a reduction in load tolerance or a change in movement patterns stress on tendon. Reduced PF strength, hip neuromuscular control problems, abnormal DF and subtalar-joint ROM, increased foot pronation, and body weight are all intrinsic risk factors that can be determined. Aside from a family history, systemic illness, and genetic variations have also been identified as inherent risk factors. Tendonopathy and tendon rupture have been connected to the use of fluoroquinolone antibiotics, with symptoms appearing eight days after therapy begins. Sport involvement, footwear, surface, training-load mistakes (such as a fast increase in training length or intensity; a reduction in recovery time), and ambient variables have all been linked to ATpathy development because to a lack of data [97, 98].

## **Symptoms**

The primary symptoms are pain and decreased function. Patients generally explain a gradual onset of symptoms with morning stiffness or after prolonged sitting, pain with palpation and activity (jumping or running), and damages in strength or performance. Activity pain can vary in terms of severity. Prior symptom can merge with the start of activity. It is fairly unusual for an athlete to have poor athletic performance (e.g., decreased jogging time or jump performance) prior to experiencing discomfort during the activity. Athletes who overlook small indications may feel discomfort during and after exertion, as well as a decline in performance. It's crucial to note that in the absence of loading, people with ATpathy typically experience no discomfort [95, 99].

## **Signs and diagnostic tests**

The subjective report of discomfort and pain with tendon palpation are both reliable and valid diagnostics for ATpathy. Palpation of pain can help distinguish between an insertional-midportion damage and a diagnosis. For example, if palpating the anterior tendon causes more discomfort than the tendon itself, os trigonum syndrome or posterior ankle impingement may be a more plausible diagnosis. Acute AT rupture, accessory soleus, systemic inflammatory illness, sural nerve, and fat-pad irritation are more factors to consider in posterior ankle discomfort [92, 97]. Additionally, diagnostic tests like as the Royal London Hospital test and the arc sign may be performed to confirm ATpathy [100, 101].

Patient-reported pain and symptoms have traditionally been used to determine severity of the condition. Nevertheless, patients also have increased fear of movement, or kinesiophobia, impaired lower extremity function, altered tendon structure and decreased muscle performance. The patient's overall condition rating, participation, pain on loading or activity or over a certain length of time, function, psychological aspects, physical function capacity, disability, and quality of life are all factors that contribute to a consensus [92, 96]. Patients with ATpathy have varying degrees of impairment and symptoms in each domain. Each component of tendon health must be assessed for diagnostic progress, patient objectives and expectations, and athlete return-to-sport decisions. In addition, structural changes might occur without causing any symptoms. Other patients may experience a few symptoms and functional impairments with no structural change. Furthermore, complete symptomatic healing does not guarantee complete functional recovery. As a result, the significant reinjury rates (27–44 percent) for ATpathy may be due to merely using symptom resolution as a recovery guide without confirming tendon health [92, 94, 99].

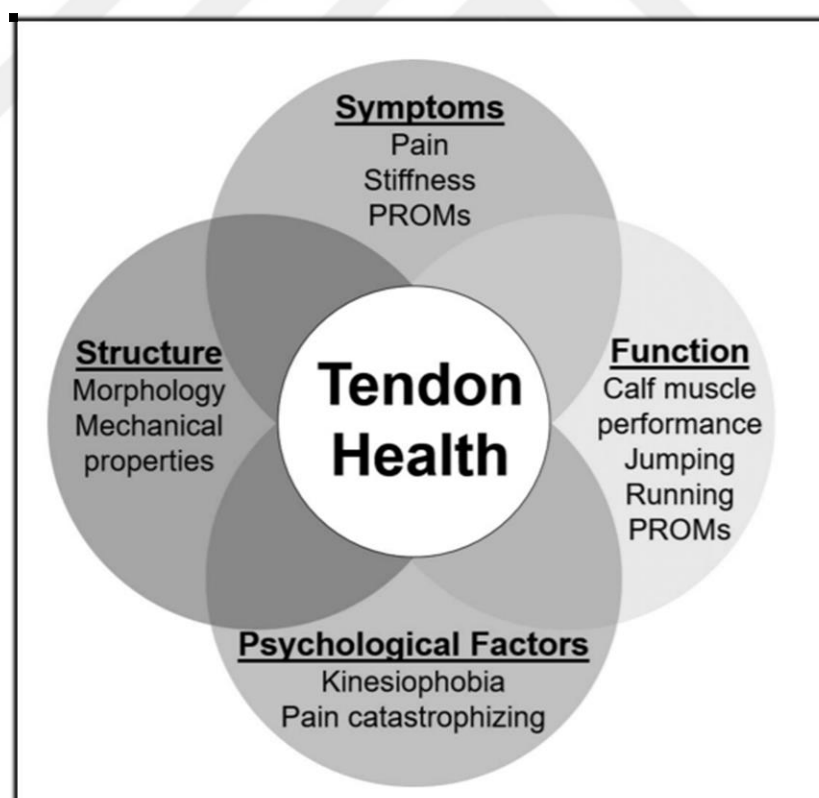


Figure 2.10. Tendon health domains [111]

Abbreviation: PROMs, patient-reported outcome measures.

## **Imaging**

Pathophysiology related with ATpathy is frequently determined by imaging. Existence of enthesophytes size, haglund deformity and intratendinous calcifications, evaluation may all be determined with lateral weight-bearing radiographs of the foot. Form and lucency of the Kager triangle on a radiograph may also be utilized to determine whether or not a patient has retrocalcaneal bursitis. Ultrasound and MRI may be used to evaluate for soft-tissue (bursitis, neovascularization, paratendinitis, tendon degeneration) as well as bony (intratendinous calcification, enthesophytes) changes. Imaging signs for tendinopathy do not necessarily induce the lack of ATpathy. In the literature, for instance, it was reported that the asymptomatic tendons percentage with signs of ATpathy on imaging range from 0-35 percent and the symptomatic tendons percentage without signs of ATpathy range from 0-19 percent [69, 102, 103].

### **2.4.9. Other Conditions**

In addition to problems arising from overpronation, supination, PFs, and ATpathy, other conditions affecting hindfoot may include arthritis, fractures, bursitis, bruises, PFa disorders -plantar fasciopathy, fibromatosis, fascial tear- and entrapped nerves (Baxter's neuropathy) [11, 22, 68].

## **2.5. TREATMENT OPTIONS**

HP cure is splitted into surgical and non-surgical treatment options. Conservative treatment is the base of cure because of 90 percent success in it. Surgical treatment is the last option method. All in all, depending on severity and response to conservative treatment, surgery of the hindfoot deformity or arthrodesis could be necessary [10, 11].

Belows are the treatment options for hindfoot pain according to the pathology basis;

### **2.5.1. Conventional Physiotherapy**

Before assessing the patient and determining to rehabilitation program, biomechanical, anatomical, and environmental agents should be considered in terms of cause. The essential adjustments must be done by observing the conditions such as weight, improper shoe selection, training errors, and overloads that may guide to this priority. These minor adjusment are significant for treatment. In recent researches indicated that treatment modalities should be combined with each other to be successful. 85-90 percent of patients

respond to conservative physiotherapy within 2-3 months and surgery can be conceived in patients who do not replied a conservative treatment for 6-12 months. Generally, the purpose of treatment should be designed to reduce inflammation, pain and tissue tension, increase tactile flexibility and muscle strength. In a choosing of HP conventional physiotherapy options, underlying pathology (that is written below) and its risk factors should be determined [11, 22, 68].

Hindfoot pain might be associated with:

- (1) Overpronation & supination and varus & valgus,
- (2) Haglund's deformity,
- (3) Retrocalcaneal bursitis,
- (4) Calcaneal stress fracture,
- (5) Heel fat pad atrophy,
- (6) Tarsal tunnel syndrome,
- (7) Plantar fasciitis, and
- (8) Achilles tendinopathy conditions.

In some cases (overpronation & supination and varus & valgus), HP can be treated or controlled by wearing proper shoes with providing cushion and stability. Simple foot and ankle stretching and strengthening exercises can also assist to relieve pain and discomfort. Overpronation can result in flat feet, which can be treated with stretching, orthotics, or surgery [11].

Conservative treatment for Haglund's deformity includes anti-inflammatory and analgesic medicines, physiotherapy, and shoe adjustments to relieve pressure on the afflicted side. The following are examples of shoe modifications [11, 104]:

- (I) wear shoes with the quarter's top trim line under or above the bone protrusion.
- (II) using heel lifts to raise the heel and avoid irritation between the deformity and the shoe's deformity-counter
- (III) using a tongue or heel pad within the shoe's heel counter to reduce stimulation throughout the gait cycle
- (IV) wearing clogs or sandals

In some researches, these shoe modifications that is written above found to be effective; but, it is still necessary to make more clinical trials for evaluating the effectiveness of shoe modifications [11, 105].

In retrocalcaneal bursitis management includes ice usage, rest, anti-inflammatory & analgesic medication, shoe modification and physiotherapy. Moreover, corticosteroid injection effectively reduces inflammation and alleviates symptoms. The most applicable shoe change is to put a heel lift inside the shoe, which prevent from compression of the retrocalcaneal bursa due to shoe counter. Slackening the shoe counter might also aid in management. However, clinical trials to examine the shoe alterations are still lacking, therefore their clinical efficacy should be examined [11, 106].

The essential therapeutic strategy for calcaneal stress fractures is to reveal mechanical load on affected sides to make it possible to natural healing. Even though the treatment interval varies depending on severity of the fracture, the approximate period is six weeks [107]. Crutches should be used for non- or partial-weight-bearing activities, and more severe activities should be avoided, to disclose mechanical strain on the foot. A cast can also successfully protect the injured foot from mechanical loading. Heel cushions or padding, when used with appropriate orthoses, help to absorb and disperse the stress on calcaneal bone. Patellar tendon-bearing (PTB) orthosis may immobilize the foot joints while also revealing the complete peak plantar pressure loading. By eliminating contact with the floor, adding a patten bottom to a PTB orthosis may help achieve non-weight bearing of the foot [11, 76].

Conservative treatment modalities of heel fat pad atrophy contain rest, ice usage, non-steroidal anti-inflammatory drugs (NSAID) and orthosis. Applicable foot orthoses are [11, 108]:

- (I) Solid ankle cushion heel, comprised of soft compressible material, which can alleviate the impact during heel strike and help push off to improve gait more inherently;
- (II) Cushioned heel pad, that helps padding and support heel during walking and reveals pain through reducing pressure on the calcaneal area;
- (III) Heel rocker soled shoe.

Tarsal tunnel syndrome of conservative treatments contain ice use, the restriction of activity, physiotherapy such as ultrasound or iontophoresis, orthosis, NSAID, and corticosteroid injections. Symptoms can be progressive if there is an ankle joint movement restriction or

compression on tarsal tunnel. Orthotic modalities include according to literature [11, 79, 109]:

- (I) Harden the ankle with no compress to tarsal tunnel by wearing shoes
- (II) Usage rigid rocker soles for decreasing pressure under the heel and foot motion.
- (III) Giving support to arch for preventing tibial nerve traction
- (IV) By slightly supporting the medial arch with the Thomas heel, you may avoid a medial weight transfer
- (V) The SACH is used to help with shock absorption and ankle mobility during heel strikes.
- (VI) Reduce stress on the tibial nerve by wearing a night splint
- (VII) Making a custom-made orthosis to keep the subtalar in a neutral posture to avoid foot eversion. Clinical research, on the other hand, revealed that assessing these orthotics is exceedingly rare.

For relieving from PFs, it was reported that a combination of rest, stretching-strengthening exercises, manual therapy modalities are more effective modalities than alone modalities in the literature [90, 110]. If home care (including patient education with home exercises and daily life modifications) doesn't help with the pain, it is important to consult a doctor and physiotherapist about the next steps, which could include physiotherapeutic modalities (supervised stretching-strengthening exercises, shockwave, ultrasound or laser therapy, glucocorticoid or platelet-rich plasma (PRP) injection, NSAID or analgesics, arch taping, orthosis) or surgery [80, 86, 111]. The following are the orthotic therapy options [11, 90]:

- (I) Heel cup: relieves strain by lifting the patient's heel for increased cushioning and control –pronation & supination
- (II) Soft heel pad: disperses pressure to reduce soreness.
- (III) Supports the medial arch with a navicular pad that relieves fascia strain.
- (IV) To avoid eversion and arch collapse, choose an internal or external medial heel wedge shoe.
- (V) Thomas heel with 12–15 mm extension on the medial border of the regular heel for arch support and decreasing PFa stress.
- (VI) Night splint for relieving shortness in the PFa by holding the foot in a neutral position.

According to the most recent consensus of the American College of Foot and Ankle Surgeons on diagnostic and treatment approaches based on the best available evidence in the

literature combined with clinical experience and patient practice, the following assertions were both acceptable and appropriate [110]:

(I) Biomechanical support, stretching and corticosteroid injections is effective and safe options.

(II) ESWT is safe and effectual.

The following statements, according to the agreement, were neither suitable nor inappropriate:

(I) NSAID are safe and efficacious in the management of the pain for acute PFs.

(II) Diagnostic ultrasonography is an vital adjuvant tool in management of non-traumatic PFs.

(IV) Other injections (amniotic tissue, platelet-rich plasma, botulinum toxin, needling, and prolotherapy e.g.) are safe and impressive.

No matter what treatment is chosen, it needs to be applied for at least six weeks. Concurrently, icing, stretching and strapping are recommended. The patient must modify work-related and daily living activities. Surgery is the last resort and surgical release does not give guarantee for a successful outcome. Surgery complications including flattening of the longitudinal arch, nerve injury and PFa rupture should be considered [73, 80, 82].

Depending on the severity, ATpathy treatment initially should be conservative and might consist of icing, NSAIDS and immobilizing the foot-lower leg (rest-discontinuing activities that lead symptoms by forced hyper- PF as well as physiotherapy (muscle stretching-strengthening, manual therapy, low-level laser therapy, shoe modifications, orthotics, steroid injections, and topical glyceryl trinitrate patches to provide relieve stress in the ankle [101, 105]. Certain modification of shoe are effective for controlling pain. Heel lifts can provide to reduce the strain on AT. Moreover, rocker-bottom shoes can help to reduce the load on the AT because of reducing PF. Furthermore, the AirHeel Brace was created specifically to treat AT and has been shown to be successful in controlling symptoms. The two linked air cells positioned beneath the heel and above the calcaneus, according to the producers, lead to pulsing compression with each stride, reducing discomfort and boosting circulation [11, 94, 101].

According to recent systematic reviews reported the other treatment options for ATpathy to induce are exercise with eccentric loading, manual therapy techniques (mulligan concept, pressure manipulation e.g.) injections therapies with Granulocyte-colony stimulating factor

(GCS), Hyaluronic Acid (HA), and PRP, and ESWT. Eccentric loading exercise is considered as the gold standard [11, 101]. Injections therapies can be used in clinics. These injections applied around the AT are controversial because of exception rather than the rule on exact location of the inflammation [92, 95]. ESWT can offer the mechanical stimulation by boosting pro-inflammation, which can help to stimulate tendon regeneration in tendinopathy. A microdialysis investigation that measured interleukins and metalloproteases following the treatment process supported these findings [92, 99]. Another approach in ATpathy is intense pulsed light (IPL). Experiments revealed that there might be physiological consequences [101]. Manual therapy, a non-invasive treatment strategy for effective soft-tissue dysfunction, is another adjuvant approach. It uses manual or portable instruments (such as the Graston technique) and can be applied to dysfunctional soft tissue locations before applying a precise amount of pressure to the defective tissue utilizing certain protocols and patterns-mobilization [11, 99, 112]. Based on the existing information in the literature, it may be concluded that the evidence does not strongly support any method. Eccentric loading exercises are often examined and regarded the gold standard of ATpathy conservative treatments that can enhance patients' functional outcomes, but further research is needed. Surgical intervention should be considered if these conservative therapy fail [11, 92, 96, 105].

### **2.5.2. Tele-rehabilitation in Physiotherapy**

Health systems are presently supported in an innovation process to enhance efficacy and efficiency in healthcare. Rehabilitation is the continuum, applied after an injury, illness or surgery, whereby a subjects get better their strength and relearns skills. There are many types of rehabilitation, like speech-language, physical, or occupational, therapies [113]. Telerehabilitation is one of them, meaning remote providing patients with rehabilitative services by using technologies of information and communication at a distance [114, 115]. It is a relatively new scientific discipline, with the first scholarly publication published in 1998. It is a branch of telemedicine. The number of telerehabilitation programs has been significantly increasing in recent years as a result of increasing technology advancements that have enabled the formation of efficient rehabilitation services. Remote monitoring of rehabilitative state and adjuvant procedure, as well as teaching and training of persons, are examples of such services. Tele-rehabilitation is an alternative to standard rehabilitation methods. Patients can establish exercise habit in real-world contexts through remotely

monitored programs overseen by physiotherapists, which are available outside the clinic procedure. Assessment, instruction, monitoring, and exercise treatments are all part of tele-rehabilitation [19, 114, 115]. Telerehabilitation services have quickly evolved in recent years and are a cost-effective option for out-patient evaluation and treatment. Furthermore, it has been utilized successfully in the domains of chronic illness prevention and management, with patients appreciating benefits such as reduced travel obstacles, flexible exercise hours, and the ability to better integrate skills into everyday life. Long treatment sessions and expensive clinical visits have been explained as connatural limitations of traditional conventional physiotherapy [18, 115, 116]. More frequent but quicker cycles of exercise and motor skill training in daily activities can be more beneficial than clinical trials duration, according to studies. Tele-rehabilitation may save money on transportation, save time, and is generally more convenient. Furthermore, people have the option to train more intensively than is available at healthcare facilities [115, 117, 118].

***The scientific recent literature reports as a summary for telerehabilitation's capability*** [115, 119, 120]:

- Improved communication allows information and medical data sharing
- Reaching rural areas' health services
- Improving the rehabilitation opportunities with computer-aided systems,
  - Enhancing life quality,
  - Reducing medical costs by improving patient numbers treated in a single day,
- Early diagnosis, treatment initiation in acute situations, reduced in-hospital stay, and continual monitoring of those at risk are all possibilities,
- decreasing travel interval.

***According to literature evidence that tele-rehabilitation mainly addresses*** [114, 117–119, 121]:

- patient assessment,
- clinical management of patient at distance,
- administration of rehabilitation remotely,
- determination of patient or caregiver needs,
- tele-consulting,
- patient, professionals and caregivers education,

- evaluation of the rehabilitation programs outcome,

For the particular application of tele-rehabilitation, the first practices composed of case studies in physiotherapy. Thereafter patient assessment has been thought as one of the first application as well as clinical management. Remote rehabilitation methods have been shown to be at least as successful as therapist assistance in a home environment. Tele-rehabilitation can provide physiotherapy or exercise programs, which are beneficial to surgical patients before and after surgery. There are several evidences that showed the positive effects of physiotherapy with tele-rehabilitation on clinical outcomes in cardiac, cancer, traumatic brain injury, musculoskeletal disorders and depression and patients. The majority of the studies focused on neurorehabilitation, however a few looked at the impacts of tele-rehabilitation in orthopaedic domains. The Rutgers Arm, virtual reality systems, web-based libraries of status tests, therapeutic games, and progress charts are examples of applications in this field of physiotherapy ( a low-cost force-feedback joystick capable of assisting or resisting movement). These technologies, as described above, create an environment in which physicians and technical workers may engage with 3D visualisations of the patient's individual data from a distance [18, 122, 123].

In the past, the chronic phase of recruitment was thought to be a static time, based on the outdated idea of a "static brain." Most investigations in recent years have shown that the brain is constantly remapped in response to brain activity. Inactivity leads to a learnt non-use, resulting in poorer special-area function. Throughout the chronic period, any exercise performed improves function, implying that if there is an impairment, it is vital to maintain an acceptable level of activity. The location in which the program is executed is one of the major stumbling blocks to its effectiveness in rehabilitation. Reduce the mortality and disability of stroke patients in an emergency condition defined by an appropriate standard of rehabilitation. The major function in the post-acute phase is now community occupational therapy, which is primarily conducted at home [124, 125]. Home rehabilitation is critical to completing the possible recovery and maintaining the desired function. Exercises done with a physiotherapist or an occupational therapist, whether supervised or self-done, are of particular importance. The following applications, along with additional tele-rehabilitation applications, are seen to be promising, however research into currently available telemedicine applications is still ongoing. In summary, the important new challenges in rehabilitation that form the foundation for the tele-rehabilitation method include exercise

intensity and kind, a new viewpoint on chronic conditions, facilitation job for movement, constraint induced movement, and home rehabilitation [122, 126].

Because of the limited sample size and inadequate research design, an overall review of the above studies concludes that there are currently no compelling evidences concerning the usefulness of tele-rehabilitation. In addition to this, the tele-rehabilitation approach is promising, and the collected data demonstrate at least a trend towards a beneficial effect of such methodology [18, 122].

### **Overview of tele-rehabilitation technologies and market trends**

There are many different technologies that may be used to deliver tele-rehabilitation services, and a growing body of research discusses how certain tele-rehabilitation technologies can be used to meet the requirements of specific populations. It might be difficult to identify and explain generic technological alternatives given the different technologies utilized to deliver tele-services. The sensory modality, as well as the method or technique of data transfer, are perhaps the most public to describe and present an easy distinction from a technical standpoint [115, 117].

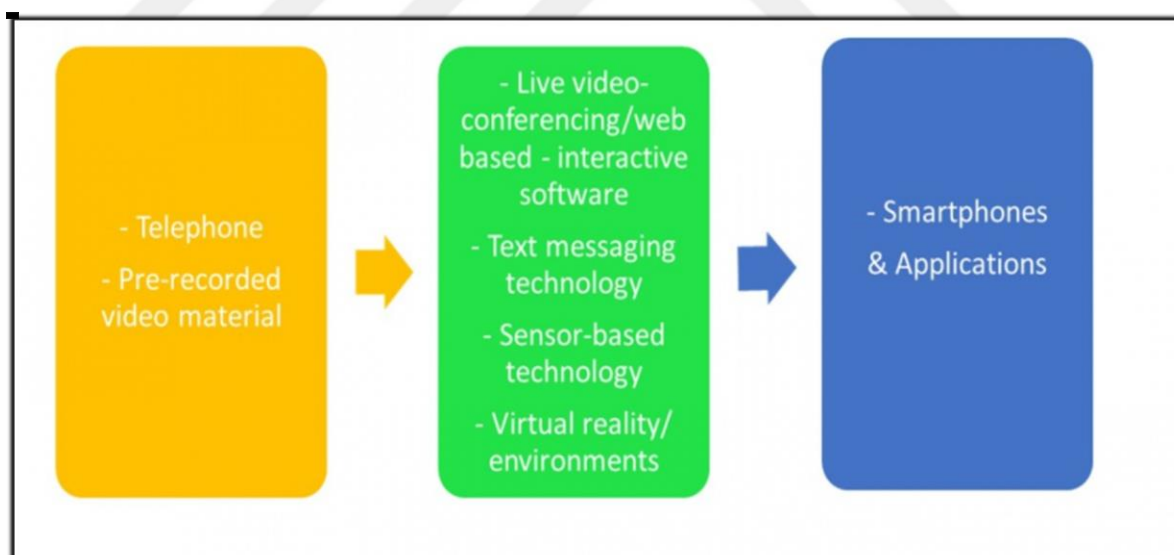


Figure 2.11. Progression of technology in tele-rehabilitation

Small pilot studies were used to characterize early tele-rehabilitation research. Clinicians used the telephone in some of the initial studies to give follow-up and complete self-assessment assessments. Tele-rehabilitation progressed in the 1980s as a result of this, with pre-recorded video content for client usage and interaction. In the 1990s, live video

conferencing was created and became well known [127]. Russell and colleagues conducted randomised control study and they assessed the efficacy of the internet-based tele-rehabilitation versus conventional physiotherapy in the rehabilitation for total knee replacement patients. Comparable results were demonstrated with the two rehabilitation methods and patients were satisfied with the tele-rehabilitation treatment [128]. Videoconferencing allows for consultations, diagnostic examinations, and treatment program delivery while also allowing for verbal and visual interaction between participants. However, the inability to quantify participants' physical performance in physiotherapy was the source of the difficulty at first. This was quickly confirmed by objectively quantifiable physical performance assessment instruments. Within the home tele-rehabilitation, improvements were made employing sensor and remote monitoring technology. These improvements allowed the patient and the rehab professional to monitor activity at home while also tracking patient compliance with specialized exercise plans [119, 129, 130].

Users can communicate with computers in real time in virtual worlds. Virtual reality begins with real-world situations that are subsequently virtualized to create surroundings that are similar to those found in the real world. It enables surgeons, physiotherapists, educators, and trainers to create settings for use in surgery, physiotherapy, education, and training [13, 131]. Smartphones have revolutionized communication in the medical field in recent years. This transformation has made it possible to provide medical assistance to people when and when they need it. According to recent statistics, half of smartphone users utilize their phone to get health information, with one fifth using health-related applications (apps). A range of smartphone-based apps are available for patients, medical practitioners, medical students, and the general public. [119, 132].

Several recent research papers have shown that the tele-rehabilitation industry is increasing and will continue to develop in the near future due to increased availability, convenience, and time savings. A recent research provided an in-depth analysis of the worldwide tele-rehabilitation industry. It predicts that the market would be worth \$160 billion by 2020, with an annual compound growth rate of nearly 27 percent [117, 133].

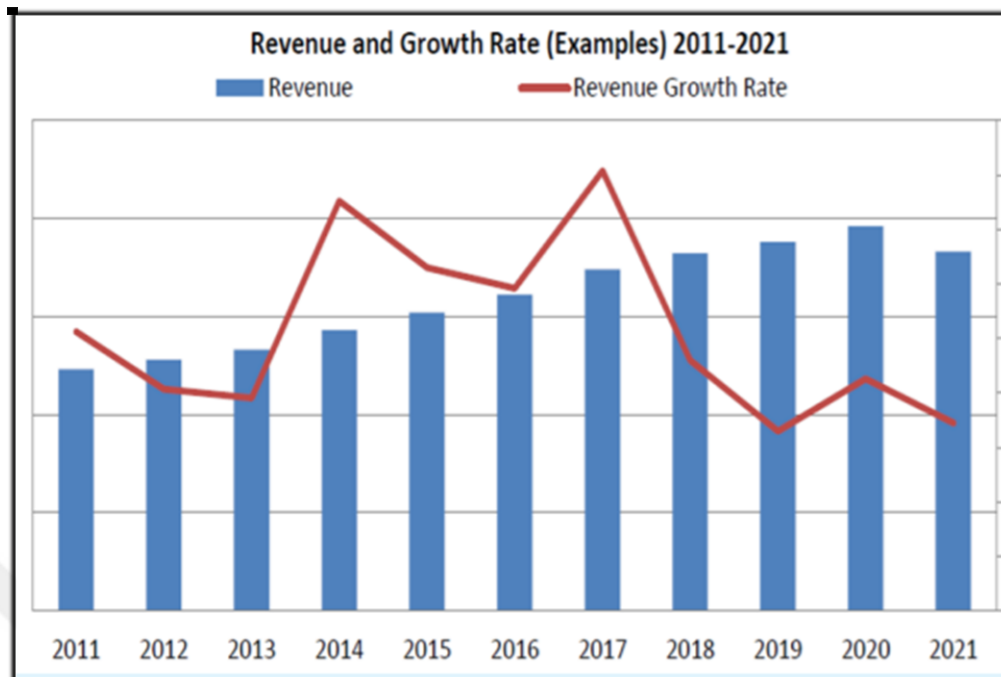


Figure 2.11. Tele-rehabilitation systems revenue and growth rate of USA [142]

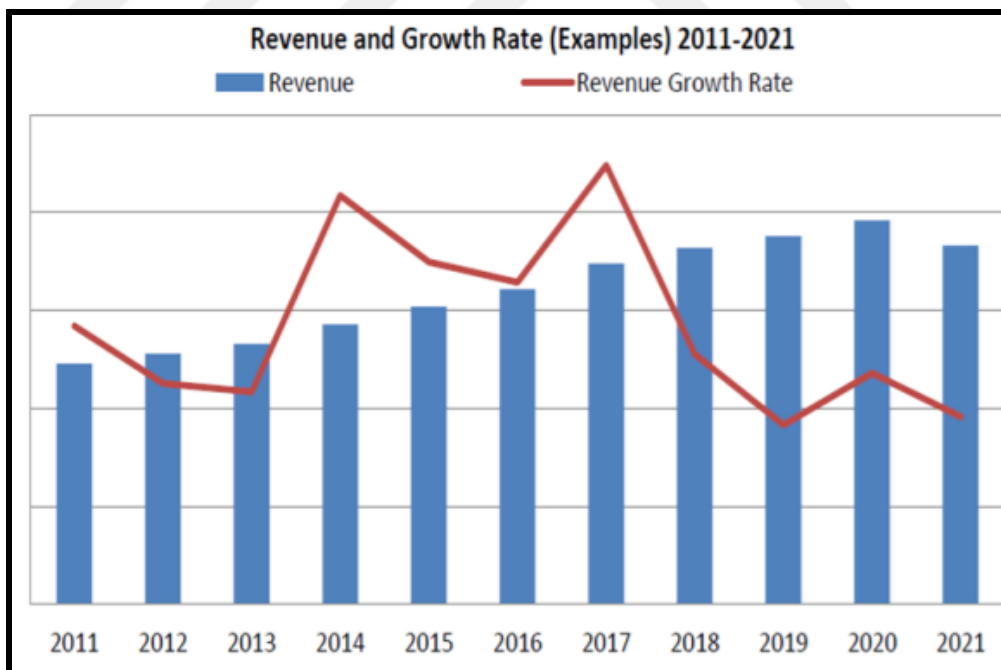


Figure 2.12. Tele-rehabilitation systems revenue and growth rate of Europe [142]

Table 2.7. Potential economic impact of healthcare market [142]

| Remote Patient Monitoring | Diabetes, Asthama, and Heart Diseases  | 200+billions dollars | ~15 billion dollars |
|---------------------------|----------------------------------------|----------------------|---------------------|
| Telehealth                | Routine Psychological care             | 100+billion dollars  | ~12 billion dollars |
| Changes of Behaviour      | Obesity, smoking & healthier lifestyle | Large indefinitely   | ~6 billion dollars  |

Recently, the tele-rehabilitation market surrounds four main sectors: 1) Controlling patients and medical devices at distance 2) Computer-assisted rehabilitation exercises 3) Communication among patients and professionals 4) training for patients or medical personnels at distance.

- Smart Devices for Active and Assisted Living, Wearable Sensors; - Smart Homes and Living Environments; - Smartphone Apps; - Security, Safety, and Privacy; - Predictive Algorithms and Intelligent Data; - Cloud Technologies; - Standardisation Issues and Interoperability; - Open data - User interfaces for Smart Things for Active and Assisted Living Health monitors (that monitor movement, pulse and skin temperature), video monitors, hip protectors, pressure mats that check if a person moves from a bed or chair, door alerts for patients who wander at night, movement detectors, balance exercises, and teleconferencing are just a few examples of common tele-rehabilitation products. [117, 119, 133, 134]

To summarize, it can be outlined technologies and marketing basis of primer sensor modality used to communicate data as; Textual-based Technologies (textual information, recording, displaying, Email, Cell phone text message), Audio-based (Voice/Sound; audio recording, telephone, MP3 players, iPods e.g.) Technologies, Vision-based Technologies (videoconferencing), Virtual Reality (commonly VR websites, multiplayer online games e.g.), Web-based Technologies (text, audio, images, video, and web-based technologies), Wireless Technologies (Personal Digital Assistants, Cell phones and smart phones, podcast e.g.), Integrated Systems (multiple sensory and technical interfaces; assistive technology, robotics, artificial intelligence)[24, 124, 129, 142] .

### **Web and smartphone based tele-rehabilitation**

Websites provide a wide range of text, audio, picture, and video interactions that may blend real-time conversation with asynchronous rehabilitative service consumption. Individuals

can interact in real time or asynchronously for education, assistance, exchanging knowledge and resources, short movies, textual content, and evaluation using the website's capabilities. For patients with chronic medical illnesses, there has been a growing interest in using websites to supplement or replace professional face-to-face intervention services. Websites can save information about past individual information, user requests, or user replies to brief evaluations and then give suggestions depending on those requirements. The research employed web-based tele-rehabilitation technology to administer and oversee self-management therapy programs for chronic diseases, as well as continuing education courses to allow professionals to maintain or refresh their professional knowledge without having to go to a conference [119, 135]. Another research was structured around the use of web-based technology to offer assessment coordination, such as that done in the VA/DoD for service personnel with brain injuries. This system includes diversity of checklists and patient-rating scales that physicians input [136].

In general, many software systems have been reported in the literature over the previous ten years. This contains patient education, exercise plan controlling, report/statistics generation, message transmitting, assignment scheduling, user control, clinical recording of the notes and exercise, video-conferencing, tele-consultation, and virtual community. Despite the fact that the techniques of workouts and reporting differed widely across the software systems studied, all of these systems included some way of controlling rehabilitative activities by adding, eliminating, or adjusting the exercise and its properties (frequency, duration, and difficulty degree) [119, 137]. The next more often used feature was ensuring patient education. After all, other features were conceived as transferring audio/text messages via the systems, scheduling tasks and user control. In the respiratory illnesses category, the most prevalent video communication systems were used for neurological problems and chronic obstructive pulmonary disease (COPD). Capacity for therapists to record clinical notes and exercises for patients, or through the software system, people may share their experiences and communicate with one another [138].

Many research have recently focused on establishing home-based rehabilitation for a variety of acute and chronic diseases (diabetes, stroke, cancer, cardiovascular disease, diabetes & musculoskeletal disorders). The biggest challenge of these programs is ensuring that patients follow the directions and perform the prescribed exercises at home without the assistance of a physiotherapist. According to surveys, two-thirds of patients do not adequately realize their workouts in the home setting [119, 139]. Improper home-based activities may have an

impact on treatment outcomes that have been postponed, and may exacerbate the condition or lead to re-injury over time. Fortunately, web-based systems have thus far provided a variety of methods for dealing with such challenges. To address home-based programs via web-based solutions, a variety of systems have been designed with a variety of approaches, purposes, and capabilities using a variety of sensors, robots, virtual reality technologies, and motion detection devices such as Nintendo Wii, Kinect, Lip Motion, and others. All of these systems are referred to as web-based for home tele-rehabilitation systems in the current study [117, 119, 127].

The internet, involving web pages usually with videos, educational content, or interactive gaming, is also studied. Studies have enquired electronic devices that are fundamentally used as remote monitors and specialized platforms (eg, for synchronous communication, videoconferencing with physical therapy. In addition for neurological area, virtual reality was used outside a health center [123, 140].

There are few research on children or adolescents, thus the group for which there is efficacy data is mostly adults. Chronic musculoskeletal discomfort, osteoarthritis, arthroplasties, and low-back pain, as well as surgically treated orthopedic problems, are all conditions in the musculoskeletal sector. The data in the field of neurorehabilitation, on the other hand, concentrates on multiple sclerosis and stroke. The diseases in the cardiopulmonary region include those that are commonly found in coronary disease or pulmonary rehabilitation, such as COPD [141, 142]. Cancer and aging were the most common illnesses in other areas of health [119, 143]. When it comes to the methods of tele-rehabilitation, the most commonly examined is smartphone usage with messaging services and calls, with knowledge of the efficacy of smartphone applications as a digital practice tool developing [14]. The rate of smartphone ownership across the world is commonly high. According to the recent Newzoo statistics, the top countries in terms of smartphone users in 2020 was reported as United States (82.2 percent), United Kingdom (79.8 percent), Germany (78.8 percent), France (78.8 percent), Turkey (64.8 percent). The rate diversifies in emerging economies such as Iran (67.3 percent), Mexico (57.4 percent), and Indian (35.4 percent) [144].

Smartphone-based tele-rehabilitation has emerged as a game-changer in terms of improving people's health and well-being by continuously assessing their status (fall risk, blood pressure, gait, and so on), behavior, and "just-in-time" treatments via user's natural surroundings [145]. Embedded sensors in smartphones, such as barometers, cameras, inertial

measurement units (IMUs), and GPS, combined with wearable technology, can supply a wealth of information about a person's health and behavior patterns [132, 145].

In most studies, the smartphone-based systems were based on rehabilitation for specific conditions. Chronic diseases attract more attention due to the fact that the efficiency of long-term rehabilitation is constricted by a lack of patient compliance to protocols and high costs of clinical visits. Moreover, the prevalence of multiple chronic disease is really more common, especially 42 percent in the United States. For improving patient lifestyle and general physical activity, such as step counts, are common patterns for providing the at-home recovery of chronic conditions [146, 147]. The most commonly used sensors are IMUs which can be either alone or in combination with EMG and heart rate monitors as sensors. IMUs are typically used to analyze posture or movement [13, 132].

The most common health situation can be considered as a stroke for smartphone-based rehabilitation, probably because of the large affected population [148, 149]. Monitoring posture and movement of the patients are mostly in this category systems. A few smartphone-based games have been improved for increasing motivation of patients for training. Additionally, a variety of smartphone-based rehabilitation apps can assist patients in regaining balance and stability while moving. IMU sensors have only been used in this type of systems so far [148–151].

Smartphone-based cardiac rehabilitation systems as a tool focuses on improvement of the patient's life quality and decreasing cardiac risk factors, generally via lifestyle changes. In this category, heart rate monitors, smart-watches or integrated bioharnesses can be used as smartphones paired [138, 152]. Furthermore, the heart rate monitoring using video images by taken with smartphone camera were also used by Chung et al. for estimation of the heart rate [152]. This technology requires the need of external devices for real-time application, but the estimation accuracy of this was restricted via motion artifacts. Moreover, the heart rate can also be monitor the activity of the respiration, blood pressure and O<sub>2</sub> saturation. For example, step counts, walking distance, physician-patient communication for lifestyle guidance can be recorded with these more mature systems for promoting patient lifestyle modifications [13, 138, 138]. Moreover, Yudi et al. developed feedback system that physiotherapist can detect patient exercise and patients can have suggestions of dietary and health tips from the application [153].

Most smartphone-based joint or limb rehabilitation (osteoarthritis, frozen shoulder e.g.) systems use simply accelerometers or IMUs for monitoring body movement during

exercises. It can be monitored movements of joint deviation angles for shoulder rotation and knee extension [154, 154]. In the literature, IMUs and pressure sensors used for measured gait behavior of lower limb rehabilitation while EMG signals were used for classifying the hand gestures and feedback on exercise for hand rehabilitation. More complex applications also provide the advanced functions like recording motivational messages or reminders.

The majority of smartphone apps for Parkinson's disease are based on gait performance evaluation, which is accomplished by installing IMU sensors at the patient's feet or by placing a smartphone on the patient's trunk [13, 155]. The another studies also reported different a system named CuPiD that supplies corrective verbal feedback for encouraging patients to remain gait parameters and helps improvement of balance [156–158].

Researches reported diversity respiratory rehabilitation strategies, containing with the encouraging general physical activity controlling respiratory exercise and gaming. In this category, Oximeter, breath belts, accelerometers, IMU sensors, GPS devices have been used to monitor general physical activities [141, 159, 160]. In the literature, the study conducted by Vorrink et al. developed more complex an application for exercise and physician intervention functions remotely [160].

In the literature, few rehabilitation systems (smartphone-based) documented have targeted the clinical conditions and general physical rehabilitation such as arthritis, cerebral palsy, chronic pain, diabetes and traumatic brain injury than described above [13, 52, 161, 162]. IMU sensors, accelerators, smart insoles are commonly used in this category for posture and motion monitoring. Kinect-based systems for monitoring the body posture can be evaluated as a new approach. Additionally, there are several other systems developed to monitor general physical activity, gait performance, step counts, posture. Many of them have integrated with wearable smart garments (smart insoles, footpads, smart jackets) footpads [13, 14, 132].

Mobile apps for the computerization of many clinical tests have also been created. Because of its relevance for clinical assessment, quick-and-easy procedures, and more moveable devices, ROM or goniometric measurement has piqued the interest of researchers. For several joints, such as the lumbar, knee, shoulder, and wrist, ROM measures have been created. Regardless of the fact that several studies have demonstrated high reliability, further validation assessments with bigger sample sizes of patients have been highlighted as a general direction for future research. Other systems for computerizing trunk endurance and exercise capacity tests, as well as functional mobility and gait evaluation, have been

developed. These systems generally use IMU sensors or an image processing approach with a smartphone camera to analyze motion or posture [163, 164]. Furthermore, the wearable EMG sensors are utilized to calculate muscular exhaustion [165].

Sufficient ankle DF is necessary for daily physical activities such as walking, running, stair climbing and rising from the sitting position [166, 166]. Therefore, inadequate ankle ROM directly affects functioning, but also leads a risk factor for injuries and other pathologies because of the altered biomechanics and movement patterns, falls in the elder people. There are several common causes of reduced ankle ROM and it might be related with lower limb injuries like ankle sprain pathological conditions such as arthrosis, diabetes, ATpathy, plantar fasciopathy, post-stroke situation, prolonged immobility and aging in the mechanical properties of muscles and soft tissues. According to these reasons, improving ankle ROM is a common physiotherapeutic goal and accurate, valid, and reliable goniometric measurements are needed for evaluating the therapeutic procedures effectiveness and planning [166]. Weight-bearing measurements are becoming increasingly prevalent and are more appropriate for assessing function than non-weight-bearing measurements. The weight-bearing measuring approach is developed as a functional position of the lower leg that is integrated with daily activities. Different tools have also been used to construct a range of measuring processes. Different goniometers, tape measures, customized equipment, and mobile applications of goniometers are the most often used measurement instruments. [164, 166]. In medicine and health sciences, a variety of smarphone based mobile apps rather than traditional measurement instrument owing to their accessibility, affordability and simplicity is a growing as a trend [163, 164] In their investigation, Williams, Caserta, and Haines used a mobile goniometer called TiltMeter to assess DF ROM in weight-bearing. With the knee extended and flexed, measuring intra-inter-rater reliability was found to be excellent (ICC 0.8 or more) [167]. Two more studies looked into the use of goniometers for weight-bearing DF measurements and found moderate to outstanding reliability and validity [176, 177]. Several research have shown that using Apple IOS system on apps for weight-bearing DF measurement is reliable, therefore utilizing -Android- smart phone apps for weight-bearing DF measurement is restricted. [163, 164, 166].

### 3. MATERIALS AND METHODS

#### 3.1. SUBJECTS

This study is divided into two according to its aims (H1). Therefore; **I**) individuals with hindfoot pain and **II**) volunteers for pilot studies of the developed smartphone applications were included in the study. Seventy seven patients with hindfoot pain (plantar fasciitis (PFs) and Achilles Tendinopathy (ATpathy)) admitted to OsteoAcademy -Sonomed Medical Imaging Center-, while total 36 subjects participated for pilot studies between November 2019 and December 2021.

##### ***I. Hind Foot Pain (HP) Patients***

The HP patients of the study (PFs-28F/11M,  $49.26 \pm 10.22$  years; ATpathy-16F/22M,  $33.00 \pm 10.07$ ) included patients who got diagnosed by senior orthopedic surgeon. Patients with one hundred twenty feet aged 18-75 years, diagnosed in terms of inclusion criteria were randomly (by computer based random number generator) splitted into three groups as conventional physiotherapy, home exercises and tele-rehabilitation group according to their pathology.

##### ***Inclusion criteria***

- Have pain in heel and surrounding region
- Have given agreement to be a volunteer for the study
- Being 18 years and older and able to use a smartphone

##### ***Exclusion Criteria***

- Injuries and surgeries to the foot and ankle in the last three months
- Prior to randomization, having been received physiotherapy or local injection prior
- Having serious pathologies while undergoing rehabilitation (complicated diabetes mellitus, severe heart and neuropsychiatric disorders)
- Neoplastic formation in foot-ankle region
- Night pain

The sample size of the study was calculated with G \* Power 3.1.9.2 program. Based on the previous study, Cohen's significant effect size coefficient was 0.4, 95 percent power and 5 percent Type I error, with a total of 102 patients (each with a high effect size obtained based on VAS measurement differences and, 34 patients in each group) since it will be appropriate

to study a total of 120 patients (40 people in each group) with a 20 percent dropout effect of the study.

## ***II. Volunteers for Pilot Studies of Smart Phone Applications (DijiA & ArdAyak)***

a) Twenty-two healthy volunteers with 44 feet (14 female and 8 male aged 18–24 years) were recruited in smartphone application –DijiA pilot study from the university population. Volunteers were excluded if they reported 1) previous lower-extremity surgery, trauma, injury within the previous 6 months; 2) known balance impairment because of a neurologic, vestibular disorder, medication use, or other; 3) pregnancy; 4) concussion within the previous 3 months, or 5) a contagious skin disease.

b) Fourteen patients with 28 feet ( 7 female and 7 male aged 21-29 years) who presented to foot deformity the senior were measured for ArdAyak smartphone application pilot stud. All patients aged 18 and up were enrolled in the trial. Patients who had an ankle arthrodesis, had an acute fracture, or otherwise had significant acute illness were excluded.

This randomized controlled study approved by Marmara University Faculty of Health Sciences Ethical Committee (No: 129) (Appendix A). The study was also registered to ClinicalTrials.gov (NCT04423900).

All participants included in the study on a voluntary basis. The aim and plan of the study was explained and informed written consent was obtained from each patient (Appendix B). The study was realized according to Declaration of Helsinki.

### **3.1.1. Research Design Processes ( Flow Chart)**

#### ***I. Hind Foot Pain Rehabilitation***

A totally 80 patients were admitted to OsteoAcademy -Sonomed Medical Imaging Center. First, all HP patients were evaluated by senior orthopedic surgeon and determined the diagnosis in terms of pathologic condition. 77 patients met inclusion criterias and divided into two groups according to their pathological conditions as PFs/ATpathy. After these separation, randomization was conducted by computer based random number generator, after these separation and each patients who already got their diagnosis were splited into three groups as conventional physiotherapy, home exercises rehabilitation and tele-rehabilitation group (Figure 3.1).

## ***II. Pilot Studies For Smart Phone Applications (DijiA & ArdAyak)***

A total of 36 people (n=72 feet) participated in the pilot studies to evaluate the reliability of smartphone applications and to test the reliability of smartphone goniometry in ankle joint DF and PF-ROM measurement comparing with UG

For DijiA smartphone application pilot study, the purpose was to test the reliability of smartphone goniometry in ankle DF & PF-ROM measurement compared with UG. According to this, twenty-two of healthy university students with 44 feet were recruited in Yeditepe University (Figure 3.1).

For ArdAyak smartphone application pilot study, the purpose was to test the reliability of smartphone foot deformity detection compared with SIDAS custom station Premium Analysis. For this reason, fourteen patients (n=28 feet) with foot deformity were included in PT Academy (Figure 3.1).

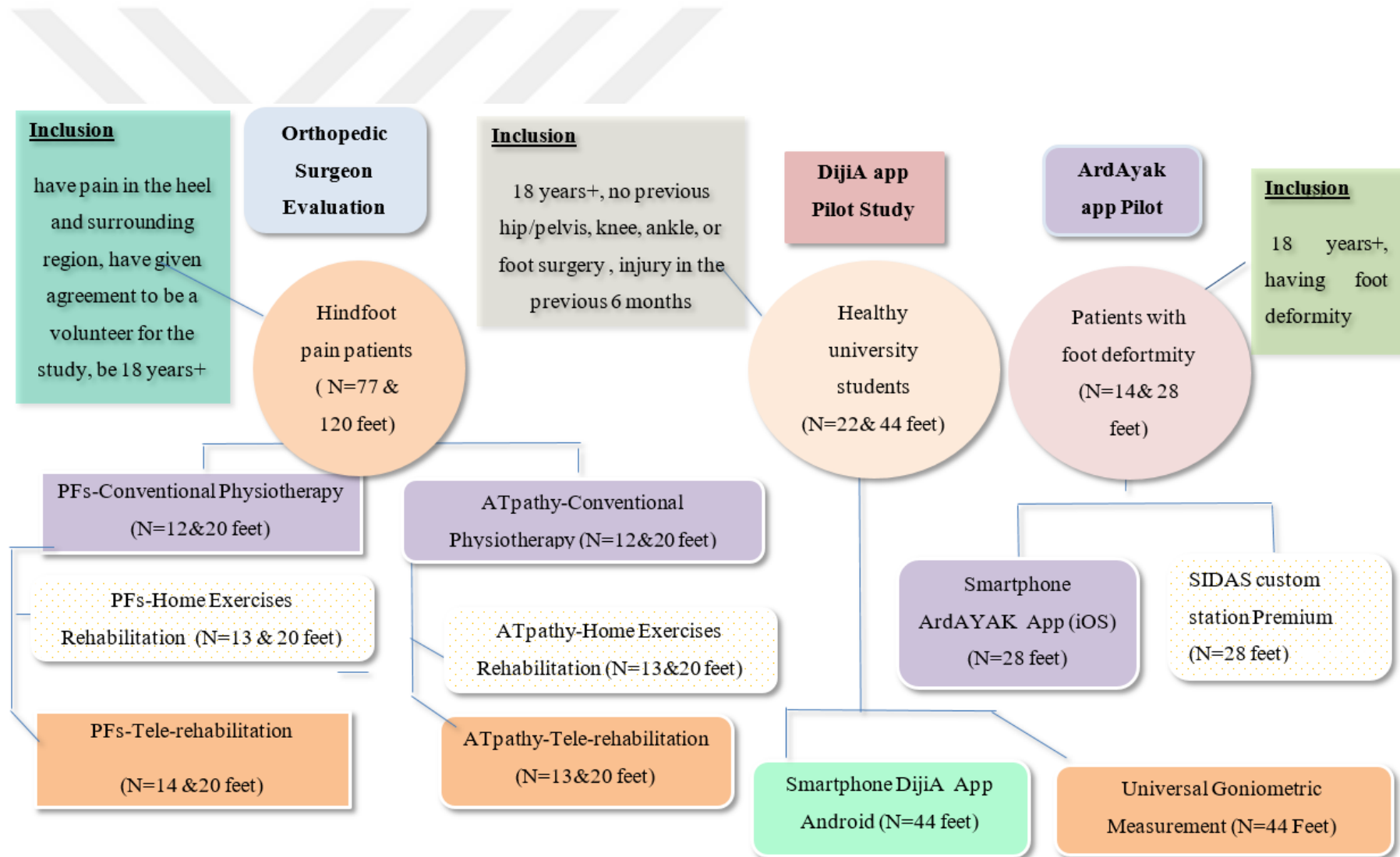


Figure 3.1. Flow chart of the study

## 3.2. METHODS

### 3.2.1. Study Design

The primary aim of this study was to investigate and compare the effectiveness of 3 different rehabilitation programs developed for individuals with hindfoot pain. The second aim was to develop analysis systems that can be remotely evaluate ankle ROM and foot deformity with smartphone applications and to investigate its reliability. According to our purposes, this study were designed to carry out in 2 stages;

*I. Hind Foot Pain Rehabilitation*

*II. Pilot Studies for Smart Phone Applications (DijiA & ArdAyak)*

### 3.2.2. Interventions ( Procedures and Protocols)

#### **I.Hind foot pain rehabilitation**

In the first stage, individuals with HP were included in three different rehabilitation protocols according to their pathologies. The first of these protocols is conventional physiotherapy including Mulligan Concept - Manual Therapy and myofascial relaxation methods and exercises programmes. Patients participated in the rehabilitation program twice a week for eight weeks, and the same physiotherapist made post-treatment evaluations. These patients performed their home exercises twice daily and for eight weeks. The home exercise programme (stretching, strengthening, self-myofascial release exercises) was given by the physiotherapist. Patients finished this program twice a day for eight weeks, and control and evaluation was performed after the completion. Patients in tele-rehabilitation programme performed their exercise program (stretching, strengthening, self-myofascial relaxation exercises) at twice a day for eight weeks via web and smartphone based tele-rehabilitation system. Following the completion of patient exercise programs, the evaluation forms sent to the participants via online system as a google-form.

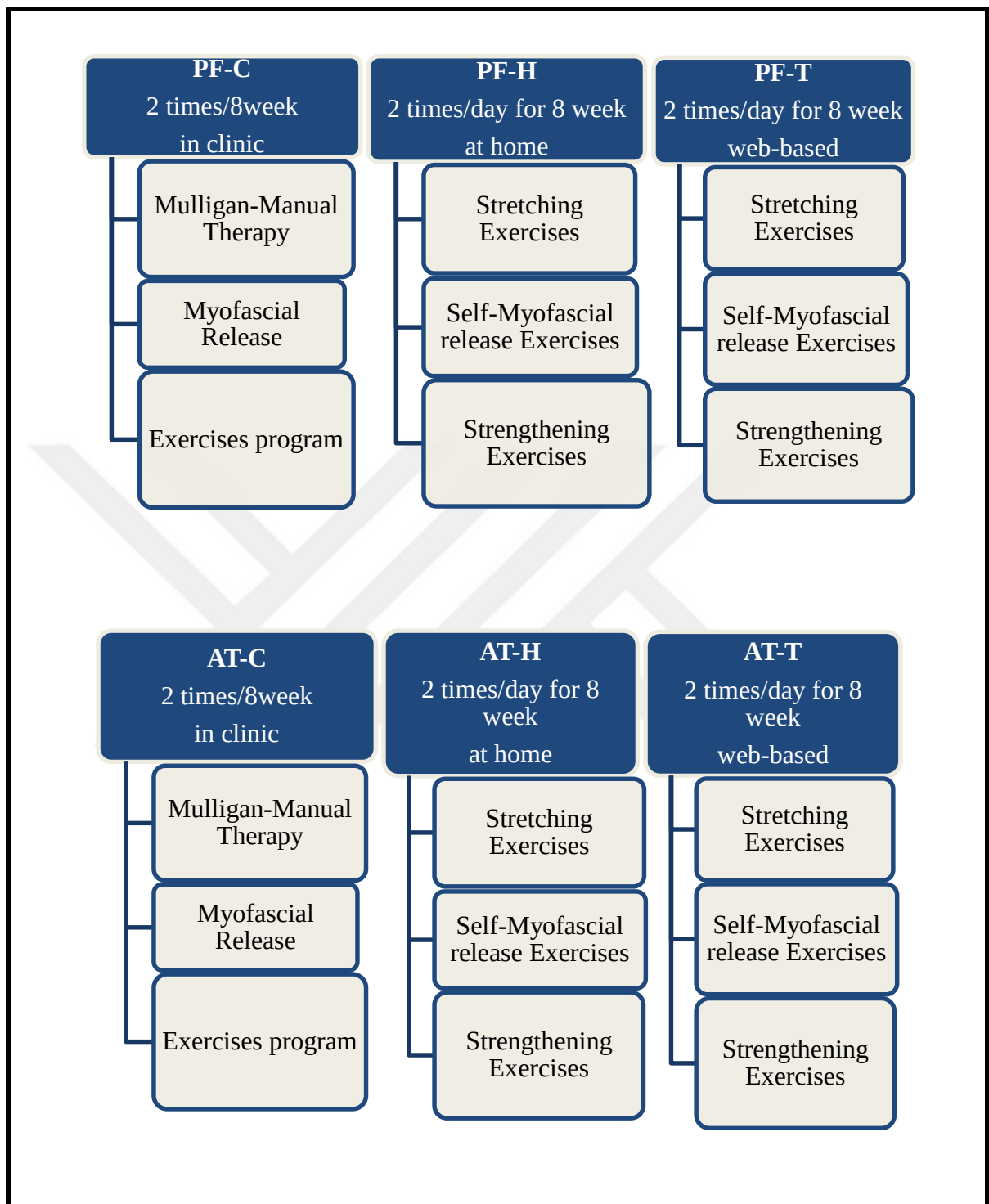


Figure 3.2. Study protocol for all groups

#### *Assessment Procedure for HP Rehabilitation*

Assessment procedures were carried out in 2 different ways;

- Orthopedic surgeon clinical examination (Appendix C)

- Physiotherapist evaluation (Appendix C)

Patients were evaluated two times; pre and post intervention.

T0 : pre intervention

T1 : post intervention (8th week)

#### *Visual Analogue Scale (VAS)*

VAS is an instrument that measure a characteristic range across a continuum. It is commonly used in researches to determine intensity or frequency of symptoms. For instance, the level of pain that patients experience might range from none to considerable. The score, which runs from 0 to 100, is calculated by calculating the length (mm) between the "no pain" pin and the patient's label on a 10-cm line. The pain is said to be more intense if the score is greater. The following cut points on the pain VAS have been measured: no pain (0–4 mm), mild pain (5–44 mm), moderate pain (45–74 mm), and severe pain (75–100 mm), according to VAS, pain scores can be inferred the severity as none, mild, moderate, or severe [168] (Appendix E).

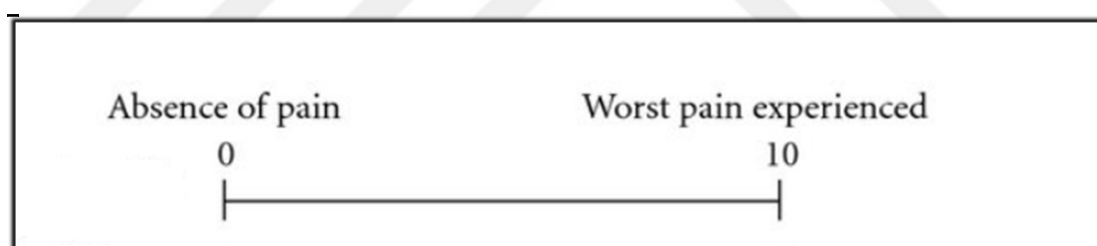


Figure 3.3. Visual Analogue Scale (VAS)

#### *Foot Function Index (FFI)*

The FFI assesses disability, pain, and activity limitations. The nine-item Pain Subscale assesses FP in relation to a number of diseases. The disability subscale, which consists of nine questions, was used to evaluate functional activities based on foot difficulties. The five-item activity limitation subscale was used to assess activity constraints due to foot issues. More discomfort, impairment, and limited activity are associated with higher ratings. In our study, patients marked to rate each category of pain severity, activity restriction, and impairment degree on a scale of zero to 10. Overall score was calculated from all of the classified scores.[169](Appendix F).

### *The Victorian Institute of Sport Assessment-Achilles Questionnaire (VISA-A)*

The VISA-A assesses clinical severity of chronic ATpathy patients. It may be used to assess a patient's clinical severity and supply treatment recommendations, as well as track the success of the therapy. The questionnaire was established as a region-specific instrument to evaluate the severity of ATpathy. It is made up of 8 questions that cover the three topics of activity, pain, and function. Scores are given on a scale of one to one hundred. Asymptomatic people would have a perfect score of 100. In cross-cultural research conducted in Turkey, it has demonstrated to be a relevant and trustworthy tool for assessing impairment. [170] (Appendix G).

### *Tampa Scale for Kinesiophobia (TSK)*

TSK is a set of seventeen questions that may be used to diagnose a variety of illnesses (musculoskeletal injuries, acute and chronic low back pain, fibromyalgia). Likert scale is a four-point scale (4 = strongly agree; 1 = strongly disagree). The patients' overall score might range from 17 to 68. The higher the scores, the more kinesiophobia there is. [171](Appendix H).

### *The Foot and Ankle Ability Measure (FAAM)*

FAAM is a self-report outcome tool for patients with foot and ankle problems to measure physical function. FAAM is a twenty-item survey divided into two subscales: Sports and Activities of Daily Living (ADL) Subscale (21 items, 8-items.) Each item was graded on a 5-point Likert scale ranging from "no problem at all" to "unable to do." The ADL subscale item score totals (ranging from 0 to 84) and the Sports subscale item score totals (ranging from 0 to 32) were converted to percentage scores. For each subscale, greater scores imply better levels of function, with 100 percent indicating no impairment [172] (Appendix I).

### *Goniometric Measurement of Ankle Range of Motion*

Universal goniometer used to measure ankle-ROM. The measurement was performed via placing a roll cushion under the measured knee side when patient was in the long sitting position [173].

*Placement of goniometer*[173]

**Pivot Point:** Lateral malleolus

**Fixed Arm:** It follows the fibula parallel to the lateral midline.

**Moving Arm:** It follows the lateral midline of the metatarsal bone.



Figure 3.4. Goniometric measurements

### **Interventions ( procedures and protocols) for hind foot pain rehabilitation**

Individuals diagnosed with PFs and ATpathy by the orthopedic surgeon were admitted in the study if they are willing to participate in preventative rehabilitation programmes. Patients were applied 3 different rehabilitation programmes (conventional physiotherapy, home exercise and tele-rehabilitation) by randomization according to their order of arrival. All rehabilitation protocol were applied according to their pathologies (PFs or ATpathy). Pre- and post-treatment (8th week) evaluations of patients in all groups were performed by the same physiotherapist.

#### **Conventional physiotherapy programmes**

In this programme, Mulligan Concept - Manual Therapy, myofascial relaxation treatments were applied twice a week for eight weeks to the individuals, and these patients conducted their home exercises twice daily for eight weeks. The home exercise follow-up were carried out through the control chart. It was applied to individuals included in the conventional physiotherapy group.

### *Mulligan Concept - Manual Therapy*

The Mulligan concept was applied by trained physiotherapists and it is a mobilization method that is widely used in the treatment of in the musculoskeletal problems. The MWM (Mobilizations with Movement) technique was developed by Brian Mulligan and it is an improved form of joint mobilization. Mulligan's on the effectiveness of MWM is that the joint is caused by the misalignment of the joint that develops secondary to injury (the basis of his original theory) and it is explained as “positional error” that causes displacement. The displacement of the joint to normal is ensured and positional error is corrected with MWM. In Mulligan, we focus on the main problems in the movement system and proceed from there, regardless of the pathoanatomical diagnosis (PFs or ATpathy). Therefore, regardless of the diagnosis, "Client Specific Impairment Measure" was determined. According to this, during examination of the patient we assessed pain when squatting, pain when PF, pain when standing on one leg, limitation of movement in DF etc. After that, a standard range of motion that reveals the patient's pain or joint range of motion (DF, Squat, Toe-up, etc.) was treated [174]. Accordingly, lateral shift or rotational force applied to the joint and while the force continues, the patient was asked to do the active movement with 10 repetitions. It was repeated in 2-3 sets with 15-20 seconds rest. All techniques totally were applied as 16 sessions (8 weeks).

#### ➤ Ankle joint-Plantar Flexion Techniques (Talocrural PF MWM)

The patient lies on the examination bed with the affected side knee and ankle bent 90 degrees. The heel was on the bed. The hypothenar region of the hand was placed proximal to the joint line and wrapped around the lower leg with the thumb and other fingers. Tibia and fibula are pushed posteriorly.

#### ➤ Ankle Joint- Dorsiflexion (Talocrural DF MWM)

The patient stood with the affected foot on the bed or chair. The belt was aligned by wrapping the upper part of the wrist 4 cm above the insertion point of the AT. Then, the web space of the hand was held with the thumb and index fingers so that it covered the anterior talus line, and the other fingers extended medially posteriorly. While the patients have not been yet fully loaded his/her foot, the tibia and fibula were pulled anteriorly with the help of a belt and the patient was asked to come forward on his/her foot and do DF.



Figure 3.5. Mobilization with Movement for ankle joint

#### *Myofascial Release Technique*

##### ➤ Myofascial Release for Triceps Surae & Achilles Tendon

Patient's position; lies face down with a pillow under the extended knee and feet hanging off the bed to allow the easy DF. Techniques; were applied by using the index, middle fingers of both hands to be get in touch with on the tendons of the gastrocnemii, fascia layer between the soleus and gastrocnemii, slowly give a line of tension in an inferior way with the pressure into popliteal fossa and keep up this down into the superior part of the fibrous portion and move to AT with the patient's passive DF and 3 repetition. After that, the patients were applied to use the fingers of both hands to be contact into the lateral and medial sides of calcaneus for releasing proximally, slowly put a line of tension in an inferior way with the patient's passive DF with 3 repetition. The line of tension were slowly constituted in a up and down forward and focused for releasing on muscles and tendon .

##### ➤ Myofascial Release for plantar myofascia

Patient's position; lies in a prone position with knee extended and feet hanging off the sickbed to make easy DF. Technique were applied by using the knuckles to provide the soft tissue of the anterior calcaneus, put a line of tension in an anterior way with the patient's passive DF with 3 repetition.



Figure 3.6. Myofascial release for Achilles tendinopathy



Figure 3.7. Myofascial release for plantar fasciitis

### *Exercises Programme*

Conventional physiotherapy and home exercises groups were given progressive stretching, strengthening, self-myofascial stretching exercises by the physiotherapist in the clinic while these exercises (Table 3.1 & Table 3.2.) were given to tele-rehabilitation group via smartphone and web based tele-rehabilitation systems. Exercises programmes were designed according to patient's pathologies (PFs or ATpathy). Patients realized this program twice a day for eight weeks, and control and evaluation were performed before and after the completion. Exercises follow-up were carried out through the control chart for conventional physiotherapy and home exercises groups.

The stretching and strengthening exercises including calf muscle stretches, PFa stretching, hamstring-gastro-soleus stretch, Strengthening of the flexor intrinsic muscles, Thera-band strengthening exercises for ankle (Table 3.1 & Table 3.2).

**Table 3.1. Exercises program for Achilles tendinopathy**

| Stage                                                  | Strength                                                                                                                                                                            | Self-myofascial release                                                                                                                                                                      | Stretching                                                                                                                                             |
|--------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Initial<br/>(weeks 1-2)<br/>pain<br/>management</b> | <p>-Isometric standing heel raise<br/>hold for 40-60 seconds 5 repeats</p> <p>-Resisted ankle (Theraband®) plantar-dorsiflexion, Inversion eversion exercises 10 repeats 3 sets</p> | <p>Self-administered PFa inhibition with a golf ball</p> <p>Golf ball tender area and near the belly of the calf. (travel upward, downward, inside and outside)<br/>40-60 sn 4-5 repeats</p> | <p>-Gentle soleus and gastrocnemius stretch (knee to wall)<br/>3 repeats 2 sets</p> <p>-Stretching of Hamstring-Gastro-Soleus<br/>3 repeats 2 sets</p> |

|                                           |                                                                                                                                                                                                                                                  |                                                                                                                                                                 |                                                                                                                                      |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|
| <b>Intermediate</b><br><b>(weeks 3-5)</b> | -Isotonic heel raise (knee straight and knee bent) one set to fatigue, no load eccentric-concentric<br>Progress to single leg by week 5<br>-Resisted ankle (Theraband®) plantar-dorsiflexion, inversion, eversion exercises<br>15 repeats 3 sets | Golf ball PFa inhibition (60 sn)<br>Golf ball tender area and near the belly of the calf. (travel upward, downward, inside and outside)<br>40-60 sn 4-5 repeats | -Continue with gastrocnemius and soleus stretching<br>5 repeats 3 sets<br>-Stretching of Hamstring-Gastro-Soleus<br>5 repeats 3 sets |
| <b>Advanced</b><br><b>(weeks 6-8)</b>     | -Isotonic heel raise 3 x 15 on step double leg, from week 6<br>Progress to single leg<br>Isotonic heel raise 8 repeats 3 sets double leg on step with 4 kg KB/backpack/Smith                                                                     | Golf ball PFa inhibition(60 sn)<br>Golf ball tender area and near the belly of the calf with across leg (travel upward, downward, inside and outside)           | -Continue with gastrocnemius and soleus stretching<br>8 repeats 3 sets<br>-Stretching of Hamstring-Gastro-Soleus<br>8 repeats 3 sets |

|  |                                                                                                                 |                      |  |
|--|-----------------------------------------------------------------------------------------------------------------|----------------------|--|
|  | -Resisted ankle<br>(Theraband®) plantar-<br>dorsiflexion, Inversion,<br>eversion exercises<br>15 repeats 3 sets | 40-60 sn 4-5 repeats |  |
|--|-----------------------------------------------------------------------------------------------------------------|----------------------|--|

**Table 3.2. Exercises program for plantar fasciitis**

| Stage                                                                    | Strength                                                                                                                                | Self-myofascial release                                                                                                                                                                                             | Stretching                                                                                                                                                                                               |
|--------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Initial</b><br><b>(weeks 1-2)</b><br><b>pain</b><br><b>management</b> | -Short Foot Exercise (SFE) n =8<br>-Towel Curl Exercises (TCE) 1 min.                                                                   | -Self-administered PFa inhibition with a golf ball (60 sn)<br>- PFa -specific stretch<br>(Hold for a count of 2 minutes x 3 sets)                                                                                   | -Gentle soleus and gastrocnemius stretch (knee to wall)<br>3 repeats 2 sets<br>Straight leg raise in supine position<br>3 repeats 2 sets<br>Stretching of Hamstring-Gastro-Soleus<br>3 repeats 2 sets    |
| <b>Intermediate</b><br><b>(weeks 3-5)</b>                                | -Resisted ankle (Theraband®) plantar - dorsiflexion, Inversion eversion exercises 10 repeats 3 sets<br>-Strengthening Exercises for Hip | -Golf ball PFa inhibition (60 sn)<br>- PFa -specific stretch<br>(Hold for a count of 2 minutes x 3 sets)<br>-Golf ball tender area and near the belly of the calf.<br>(travel upward, downward, inside and outside) | -Continue with gastrocnemius and soleus stretching (option: seated with Theraband® use or downward walking dog stance)<br>5 repeats 3 sets<br>-Straight leg raise in supine position<br>5 repeats 3 sets |

|                                 |                                                                                                                                                                                 |                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                         |
|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                 | 10 repeats 3 sets                                                                                                                                                               | 40-60 sn 4-5 repeats                                                                                                                                                                                                                                            | -Stretching of Hamstring-Gastro-Soleus<br>5 repeats 3 sets                                                                                                                                              |
| <b>Advanced<br/>(weeks 6-8)</b> | -Resisted ankle<br>(Theraband®) plantar -<br>dorsiflexion, Inversion<br>eversion exercises 20<br>repeats 3 sets<br><br>-Strengthening<br>Exercises for Hip<br>20 repeats 3 sets | -Golf ball PFa inhibition(60 sn)<br>- PFa -specific stretch<br>(Hold for a count of 2 minutes x 3 sets)<br>-Golf ball tender area and near the<br>belly of the calf with across leg<br>(travel upward, downward, inside and<br>outside)<br>40-60 sn 4-5 repeats | -Continue with gastrocnemius and<br>soleus stretching<br>8 repeats 3 sets<br>-Straight leg raise in supine position<br>8 repeats 3 sets<br>-Stretching of Hamstring-Gastro-<br>Soleus<br>repeats 3 sets |

### *Tele-rehabilitation Program*

#### *Design of the smartphone enabled website for Tele-rehabilitation Programs*

This intervention is a web-based software with a webpage as the user interface (the front end). The app's introduction web page is seen in figure 3.6. Users may use any normal web browser to access the app from a smartphone, a computer, a tablet, or even a digital television that is linked to the internet.

This software also features an administrator module, which allows the administrator to keep track of all the activity of the app's users. It may also create various reports based on the user's interactions with the app. Tele-rehabilitation group was given their exercises program via web and smarphone based systems that are mentioned above. This web-based app can be accessed from the registered website name [www.dijitaladimlar.yeditepe.edu.tr](http://www.dijitaladimlar.yeditepe.edu.tr).

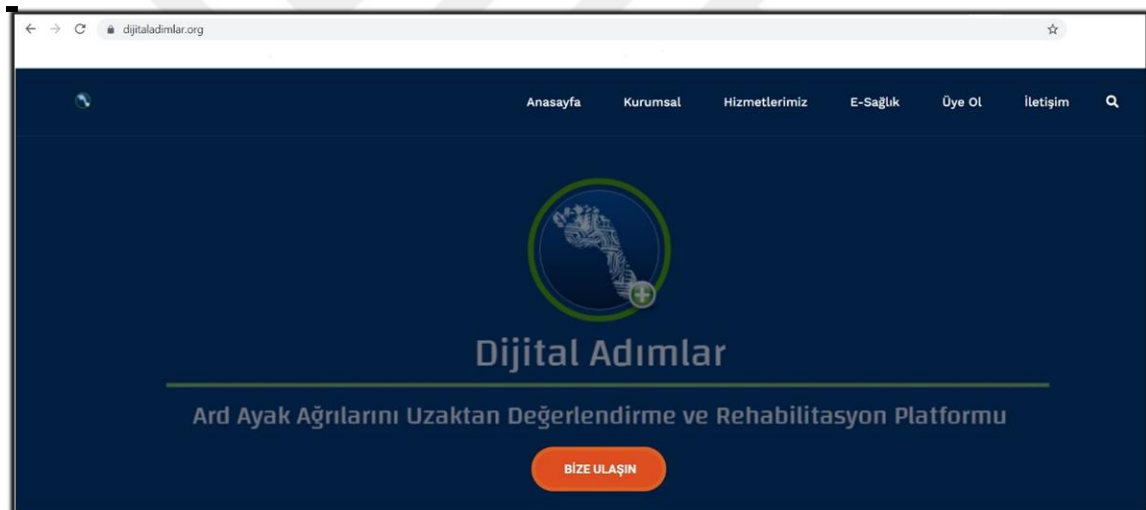


Figure 3.8. Website- [www.dijitaladimlar.yeditepe.edu.tr](http://www.dijitaladimlar.yeditepe.edu.tr).

Patients in this group were asked to become member of the [www.dijitaladimlar.yeditepe.edu.tr](http://www.dijitaladimlar.yeditepe.edu.tr) website before participating in the exercise programs (Figure 3.8 & Figure 3.9).

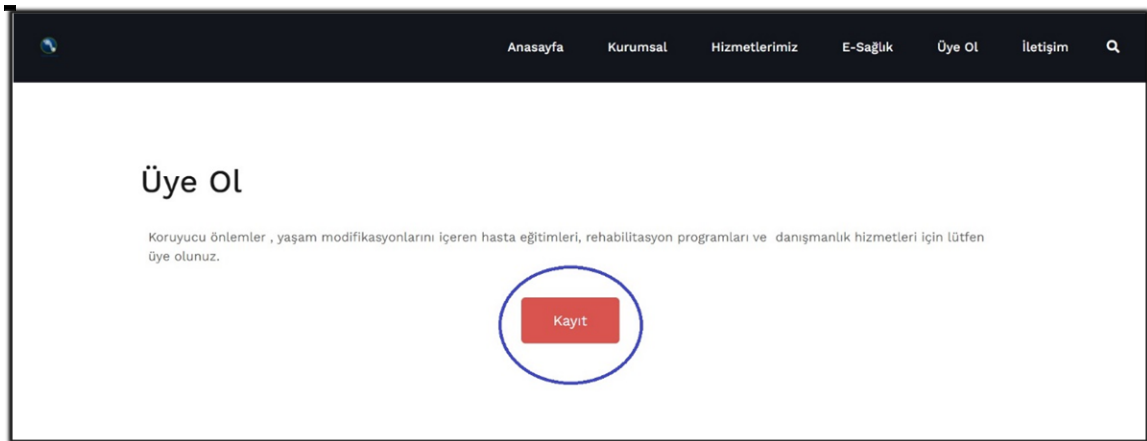


Figure 3.9. Registration- www.dijitaladimlar.yeditepe.edu.tr.

This page includes an icon for first-time users to register with user name and password sections to be filled to sign into the app (Figure 3.10).

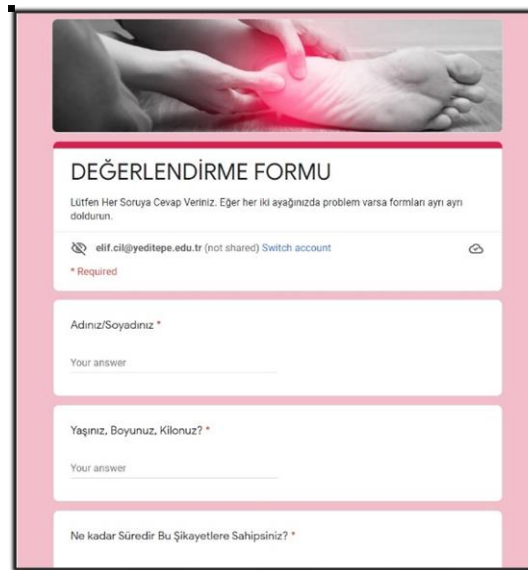
Figure 3.10. Registration- www.dijitaladimlar.yeditepe.edu.tr.

Individuals whose completed member registrations were included in the exercise programs in separate tabs according to their pathologies (Figure 3.11).



Figure 3.11. Rehabilitation Programmes- [www.dijitaladimlar.yeditepe.edu.tr](http://www.dijitaladimlar.yeditepe.edu.tr)

Evaluation forms, which were required to be filled by individuals before starting the exercise program, were delivered to the individuals via the evaluation button on the website (Figure 3.12).



**DEĞERLENDİRME FORMU**

Lütfen Her Soruya Cevap Veriniz. Eğer her iki ayağınızda problem varsa formları ayrı ayrı doldurun.

 elif.cil@yeditepe.edu.tr (not shared) [Switch account](#)

\* Required

Adınız/Soyadınız \*

Your answer

Yaşınız, Boyunuz, Kilonuz? \*

Your answer

Ne kadar Süredir Bu Şikayetlere Sahipsiniz? \*

Figure 3.12. Online evaluation forms

The exercise program in the Table 3.1 & Table 3.2 was shown to the individuals through video simulation (visual and audio). The exercise videos on the website are progressively separated from week to week and pathologies, and individuals could be accessed online from both their smartphones, laptops and computers (Figure 3.13 & Figure 3.14). Individuals were asked to follow this exercise program for twice a day -eight weeks, and at the end, they were asked to fill out the evaluation forms as online.

Anasayfa Kurumsal Hizmetlerimiz E-Sağlık Üye Ol

## Aşıl Tendinopatisi Egzersiz Programı

Egzersiz Programınız 8 hafta sürecektir. Yapmanız gereken egzersizler haftalara göre bölünmüştür. Lütfen haftalarınızı takip ederek giriş yapınız. Egzersiz programınıza başlamadan gelişim parametrelerinizi takip edebilmemiz için lütfen değerlendirme formunu doldurunuz.

[Değerlendirme Formu](#)

### 1. ve 2. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi | Germe Egzersizleri-1 | Germe Egzersizleri-2 | Parmak Ucuna Kalkış Egzersizi | Ayak Bileği Kuvvetlendirme Egzersizleri-1 | Ayak Bileği Kuvvetlendirme Egzersizler-2 |
|-------------------------|----------------------|----------------------|-------------------------------|-------------------------------------------|------------------------------------------|
|                         |                      |                      |                               |                                           |                                          |

Anasayfa Kurumsal Hizmetlerimiz E-Sağlık Üye Ol İletişim

### 3-5. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi      | Germe Egzersizleri-1               | Germe Egzersizleri-2               | Parmak Ucuna Kalkış Egzersizi      | Ayak Bileği Kuvvetlendirme Egzersizleri-1 | Ayak Bileği Kuvvetlendirme Egzersizler-2 |
|------------------------------|------------------------------------|------------------------------------|------------------------------------|-------------------------------------------|------------------------------------------|
|                              |                                    |                                    |                                    |                                           |                                          |
| 60 sn, 5 tekrar, günde 2 kez | 30 sn bekle, 5 tekrar, günde 2 kez | 30 sn bekle, 5 tekrar, günde 2 kez | 15 sn bekle, 5 tekrar, günde 2 kez | 15 tekrar, 3 set, günde 2 kez             | 15 tekrar, 3 set, günde 2 kez            |

### 6-8. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi      | Germe Egzersizleri-1               | Germe Egzersizleri-2               | Parmak Ucuna Kalkış Egzersizi                                         | Ayak Bileği Kuvvetlendirme Egzersizleri-1 | Ayak Bileği Kuvvetlendirme Egzersizler-2 |
|------------------------------|------------------------------------|------------------------------------|-----------------------------------------------------------------------|-------------------------------------------|------------------------------------------|
|                              |                                    |                                    |                                                                       |                                           |                                          |
| 60 sn, 5 tekrar, günde 2 kez | 30 sn bekle, 8 tekrar, günde 2 kez | 30 sn bekle, 8 tekrar, günde 2 kez | 10 sn bekle, 8 tekrar, günde 2 kez, 2 şer kg ağırlık ile (total 4 kg) | 15 tekrar, 3 set, günde 2 kez             | 15 tekrar, 3 set, günde 2 kez            |

Figure 3.13. Tele-rehabilitation for Achilles tendinopathy

Plantar Fasiit Egzersiz Programı

Egzersiz Programınız 8 hafta sürecektir. Yapmanız gereken egzersizler haftalara göre bölünmüştür. Lütfen haftalarınızı takip ederek giriş yapınız. Egzersiz programınıza başlamadan gelişim parametrelerinizi takip edebilmemiz için lütfen değerlendirme formunu doldurunuz.

[Değerlendirme Formu](#)

1. ve 2. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi | Germe Egzersizleri-1 | Germe Egzersizleri-2 | Havlu Toplama Egzersizi-1 | Havlu Toplama Egzersizi-2 |
|-------------------------|----------------------|----------------------|---------------------------|---------------------------|
|                         |                      |                      |                           |                           |

3-5. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi      | Germe Egzersizleri-1               | Germe Egzersizleri-2               | Ayak Bileği Kuvvetlendirme Egzersizleri-1 | Ayak Bileği Kuvvetlendirme Egzersizleri-2 | Kalça Kuvvetlendirme Egzersizleri-1 | Kalça Kuvvetlendirme Egzersizleri-2 |
|------------------------------|------------------------------------|------------------------------------|-------------------------------------------|-------------------------------------------|-------------------------------------|-------------------------------------|
|                              |                                    |                                    |                                           |                                           |                                     |                                     |
| 60 sn, 5 tekrar, günde 2 kez | 30 sn bekle, 5 tekrar, günde 2 kez | 30 sn bekle, 5 tekrar, günde 2 kez | 10 tekrar, 3 set, günde 2 kez             | 10 tekrar, 3 set, günde 2 kez             | 10 tekrar, 3 set, günde 2 kez       | 10 tekrar, 3 set, günde 2 kez       |

6-8. Haftalar Egzersiz Programı

| Top Yuvarlama Egzersizi      | Germe Egzersizleri-1               | Germe Egzersizleri-2               | Ayak Bileği Kuvvetlendirme Egzersizleri-1 | Ayak Bileği Kuvvetlendirme Egzersizleri-2 | Kalça Kuvvetlendirme Egzersizleri-1 | Kalça Kuvvetlendirme Egzersizleri-2 |
|------------------------------|------------------------------------|------------------------------------|-------------------------------------------|-------------------------------------------|-------------------------------------|-------------------------------------|
|                              |                                    |                                    |                                           |                                           |                                     |                                     |
| 60 sn, 5 tekrar, günde 2 kez | 30 sn bekle, 8 tekrar, günde 2 kez | 30 sn bekle, 8 tekrar, günde 2 kez | 15 tekrar, 3 set, günde 2 kez             | 15 tekrar, 3 set, günde 2 kez             | 15 tekrar, 3 set, günde 2 kez       | 15 tekrar, 3 set, günde 2 kez       |

Figure 3.14. Tele-rehabilitation for plantar fasciitis

## **Pilot studies for smart phone applications (DijiA & ArdAyak)**

### *Pilot Study Design*

For the second stage,

- a) DijiA application was developed for Android smartphone to measure ankle DF and PF ROM remotely. The purpose of the pilot study was to test the reliability of DijiA in ankle DF & PF-ROM measurement compared with UG. According to this, twenty-two of healthy university students with 44 feet were recruited in Yeditepe University. All subjects were applied applications' evaluation\* form before testing. After completion of testing, all of the participant were filled out the system usability scale (SUS) survey for measuring usability of application.
- b) ArdAyak application was designed for iPhone to detect foot deformity remotely. The purpose of the pilot study was to test the reliability of ArdAyak compared with SIDAS custom station Premium Analysis. For this reason, fourteen patients (n=28 feet) with foot deformity were included in PT Academy. All subjects were applied applications' evaluation\* form before testing.

\* Smartphone application evaluations [age, gender, existing chronic diseases, surgical conditions and injuries, morning, activity and severity of night pain and system usability scale (SUS) survey for android] (Appendix D)

### **General characteristic of the smartphone applications**

Smart phone apps were written primarily in native (Turkish) language and designed for the collection of socio-demographic and specific information of the foot and ankle region. A consent page under the privacy policy of the KVK (Turkish Personal Data Protection) was available for individuals before going to the app's home page. Then, Participants were asked to give information about their sociodemographic characteristics [age, gender, height, weight], dominant side, diabetes mellitus, neurological and internal diseases, the history of the ankle injury, trauma, and surgery (Appendix D). The severity of the foot and ankle morning, activity, and night pain were assessed using VAS (Appendix E, Figure 3). The interface were designed to be user-friendly and straightforward in order to avoid problems caused by a lack of technological knowledge.

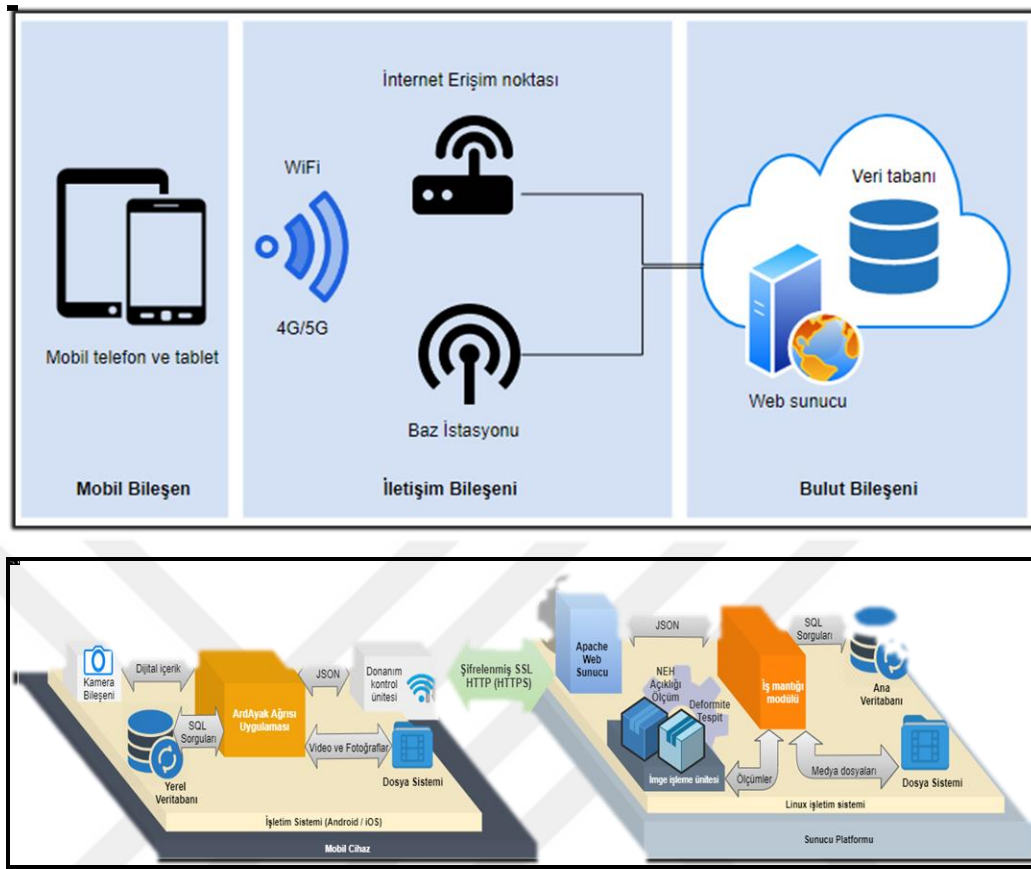


Figure 3.15. General System Architecture of smartphone applications

### General System Architectures Of Smartphone Applications

Mobile component includes mobile devices that can run on Android and IOS operating systems, and on which the DijiA and ArdAyak apps, which were designed to collect socio-demographic information of individuals and special information on the ankle area, in Turkish. The app was intended to provide interaction between the platform to be developed and the users. It was planned to deliver user data to the platform over the same system infrastructure and to deliver special exercise programs to individuals.

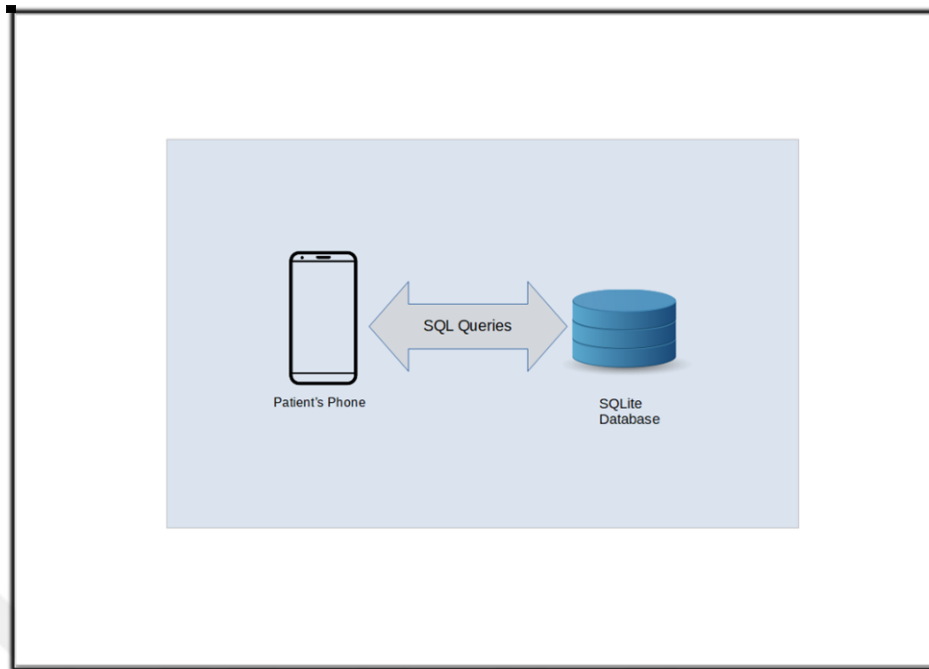


Figure 3.16. Applications in patient phone and local database

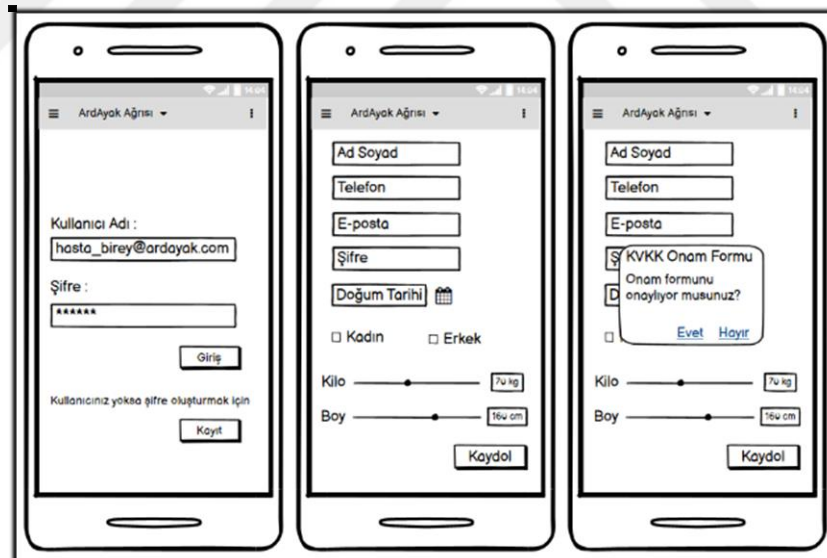


Figure 3.17. Mobile Component of the applications

Cloud component is a platform that stores the collected data on the designed platform to provide access to these data via a web server. Additionally, services development is considered for ROM measurement and deformity detection served within the scope of the

component. The web server with a user interface that both meet the data coming from the communication component and provide access to the information collected in the main database. The data from the communication component can come to the business logic module via the web server. The data were saved and the requested informations were extracted from the main database. Media files sent to the cloud component was saved in the file system to be used in developed services. The outputs of the services were processed into the database with the business logic module. The following sub-headings detail the services (ROM measurement, deformity detection) provided by the cloud component, storage solutions and web interface.

Communication component, the characteristics of the data exchange between the hardware control unit in the mobile component and cloud components are within this component. When the mobile component has access to the internet via mobile data or wifi channels, it is transferred data between the two components.

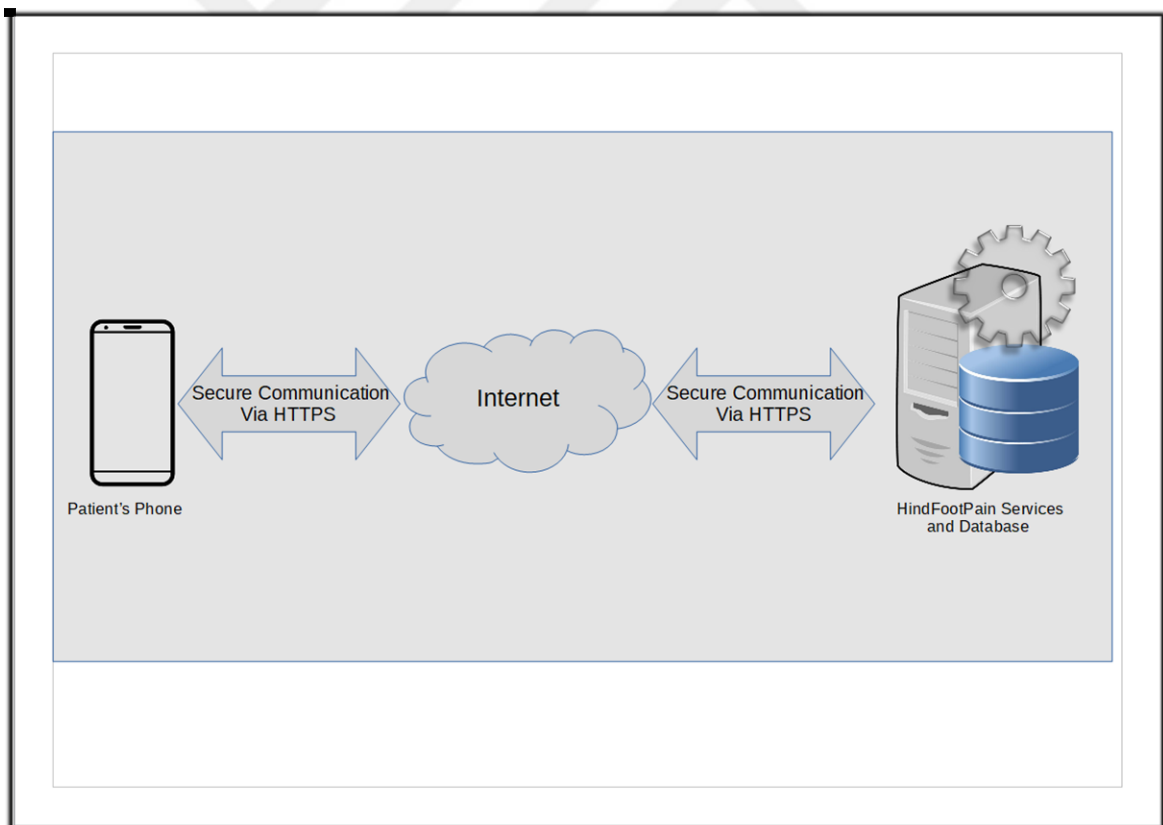


Figure 3.18. Communication of smartphone applications with services and database

### Smart phone application evaluations

The structured questionnaire prepared by the researcher was done via smartphone applications. The first part of the questionnaire included age, weight, height, gender, existing chronic diseases, surgical conditions and injuries, morning, activity and severity of night pain. Second section of the questionnaire focused on the System Usability Scale (SUS), which is a "quick" and reliable tool. It consists of a ten-item questionnaire with five response alternatives (strongly agree-strongly disagree) that assesses a wide range of items and services (software, hardware, mobile devices, websites, and apps). Based on studies, SUS scores above a 68 could be considered above average and anything below 68 is below average. (Appendix D)

### *Dijital Adımlar (DijiA)*

The DijiA app was initially downloaded from the Google Play Store and available offline. Information from the patient was stored in an SQLite database on the mobile device (Figure 3.16). It was developed a ROM detection algorithm that uses image processing and deep learning techniques via the mobile app that works on the server. Patients' ROMs were determined by the video shooting stage in the mobile app. During the video recording phase, the patients were asked to perform DF and PF movement with a rolled towel or / pillow under the knee in a long sitting position. The steps of this procedure were presented to patients with a video simulation through the app. The 2D skeleton model created by heel analysis services image processing techniques on the server where the video uploaded from the patient's phone was available to determine the angle between the DF and PF positions of the foot and access to the normal range of motion information (Figure 3.19).



Figure 3.19. The 2D skeleton model of DijiA app

After the optimization and testing of the mobile app was completed, the individuals who volunteered to participate in the study were asked to download the mobile app to their phones in order to carry out the pilot study. Individuals entered their information through the app after that they downloaded to their phones and sent their ankle normal range of motion measurements by taking videos over the app (Figure 3.20 & Figure 3.21).

The screenshot displays the 'Dijital Adımlar' application interface, which is a registration form. The form is divided into several sections:

- Personal Information:** Fields for 'Ad' (First Name) and 'Soyad' (Last Name), a WhatsApp icon, 'Doğum Tarihi' (Date of Birth), 'Kilo' (Weight) with a slider from 70 to 160 kg, and 'Boy' (Height) with a slider from 160 to 180 cm.
- Medical History Section 1:** 'Kronik (süreçten) bir hastalığınız var mı? (Birden Fazla Seçenek İşaretleyebilirsiniz)' (Do you have a chronic (ongoing) disease? (You can select more than one option)). Options include 'Kronik (süreçten) bir hastalığım yok' (I have no chronic (ongoing) disease), 'Bel Ağrısı (fıtık dahil)' (Back pain (including hernia)), 'Dahili Hastalıklar (Tiroid, Hipertansiyon, Kalp rahatsızlıkları vb.)' (Internal diseases (Thyroid, Hypertension, Heart diseases, etc.)), 'Nörolojik (Parkinson, Multiple skleroz, felç)' (Neurological (Parkinson, Multiple sclerosis, stroke)), 'Dişabet (Tip1 veya Tip2)' (Diabetes (Type 1 or Type 2)), and 'Diğer' (Other).
- Medical History Section 2:** 'Son 3 ayda herhangi bir yaralanma/ travma/ameliyat geçirdiniz mi? (Birden Fazla Seçenek İşaretleyebilirsiniz)' (Did you have any injury/ trauma/ surgery in the last 3 months? (You can select more than one option)). Options include 'Yaralanma/Travma geçirmedim' (I did not have an injury/trauma), 'Ayak - Ayak Bileği' (Foot - Ankle), 'Ouz' (Swelling), 'Kalça' (Hip), and 'Diğer' (Other).
- Pain Assessment Section:** 'Sabah ilk adımınızda topuk ve ayak tabanınızdaki ağrınızı değerlendirin.' (Evaluate the pain in your heel and the bottom of your foot in your first step in the morning). A scale from 0 to 10 is shown. Below it, 'Aktiviteyle artan ağrınız var mı? Aşağıda işaretleyin' (Do you have pain that increases with activity? Mark below). Another scale from 0 to 10 is shown. Then, 'Ağrınızın yerini işaretleyiniz' (Mark the location of your pain) with an image of a foot and a legend for 'HAFTA' (Week) and '1'.
- Next Steps:** 'SAG AYAK VIDEOSU YUKLEYİN' (Upload Right Foot Video), 'YUKLE' (Upload), 'SOL AYAK VIDEOSU YUKLEYİN' (Upload Left Foot Video), and 'YUKLE' (Upload).

Figure 3.20. Dijital Adımlar application

After individuals uploaded their videos to the system, they answered the usability tests for evaluating the mobile app. The usability test was carried out on the prototype of the mobile device app so that the latest releases contain messages that are clear, effective, consistent with the goal, and readily understood by the target audience, and do not elicit negative responses (Appendix D). This test were given researchers information about how individuals perform on questions and the app (colors, music, sounds, timing). In the pilot trial, mixed methods (observation directly, interviews with individual, and satisfaction surveys) was used to explain areas of improvement in a cross-sectional manner.

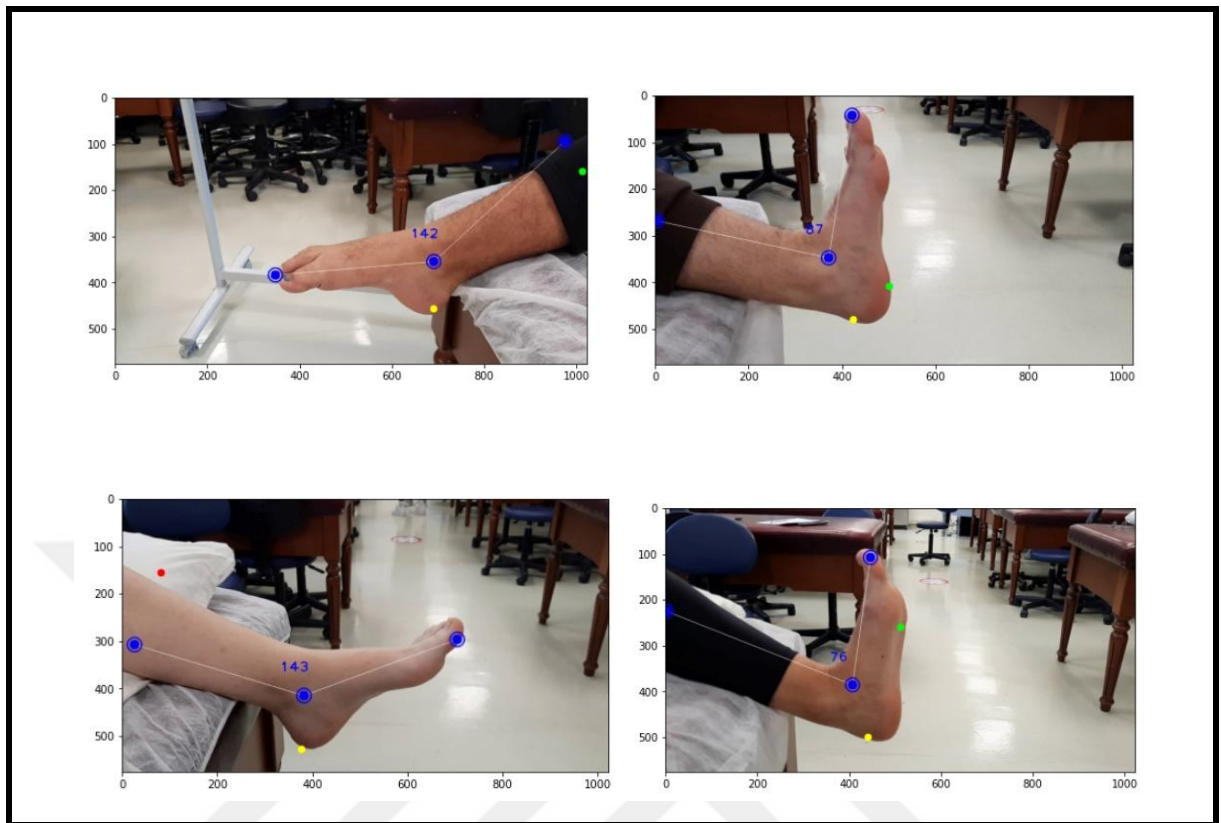


Figure 3.21. Range of motion measurement with DijiA app

### ***ArdAyak Application***

The ArdAyak app was initially downloaded from the App Store and available offline (Figure 3.22). Patient information was stored in an SQLite database on the mobile device (Figure 3.16).

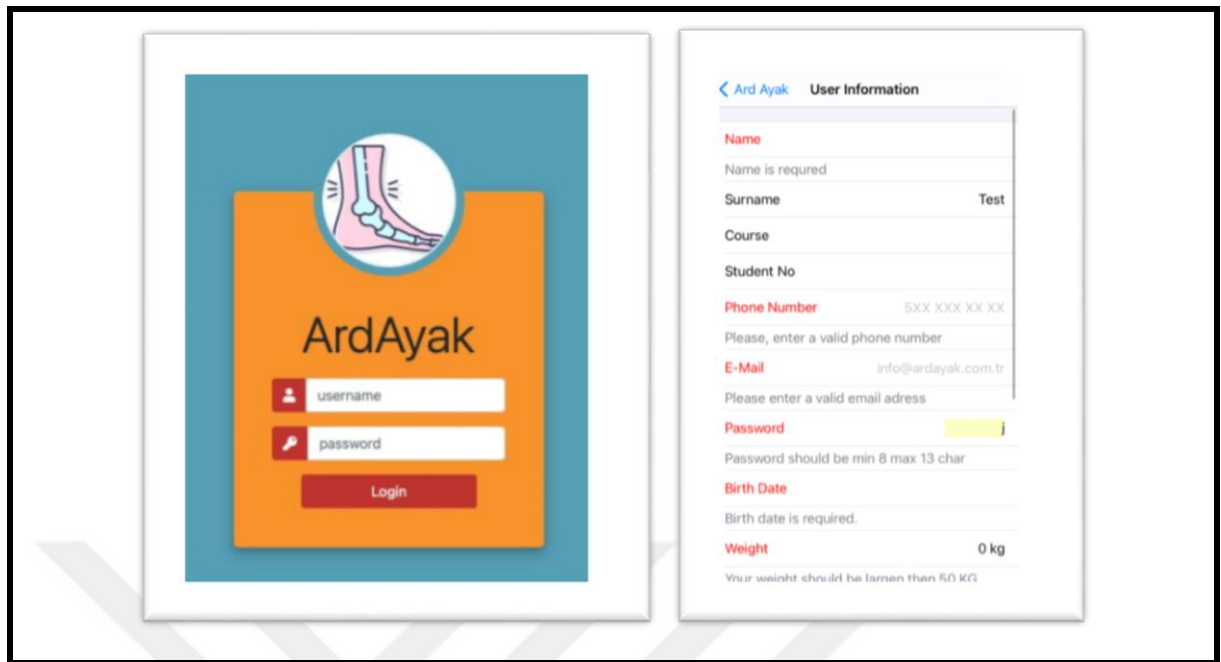


Figure 3.22. ArdAyak smartphone application

This step included sending photos from the user for foot deformity detection and confirmation. In the first stage, the patients sent a photo of their feet through the app on smartphone. Patients took photographs of their right and left legs separately in front of a flat wall while standing. The photo uploaded to the server via a secure communication path was able to classify the foot deformities through the heel analysis services. The classification was done on the photograph by using image processing and deep learning techniques through this service. The implementation steps were 1) region of interest (deep learning), 2) image preparation (detect the contour of the foot's sole- Sobel edge detection algorithm), 3) image processing (foot line detection), 4) after the foot sole is extracted, the Arc index was calculated. This calculation is based on the ratio of critical points in the foot, which does not require reversal of the perspective transformation. Furthermore, the points location (top, bottom, and metatarsal) calculated using foot solo equation (Figure 3.23). All collected data was analyzed and stored by analysis systems established on an external server (Figure 3.18). Datas were transferred securely over HTTPS.

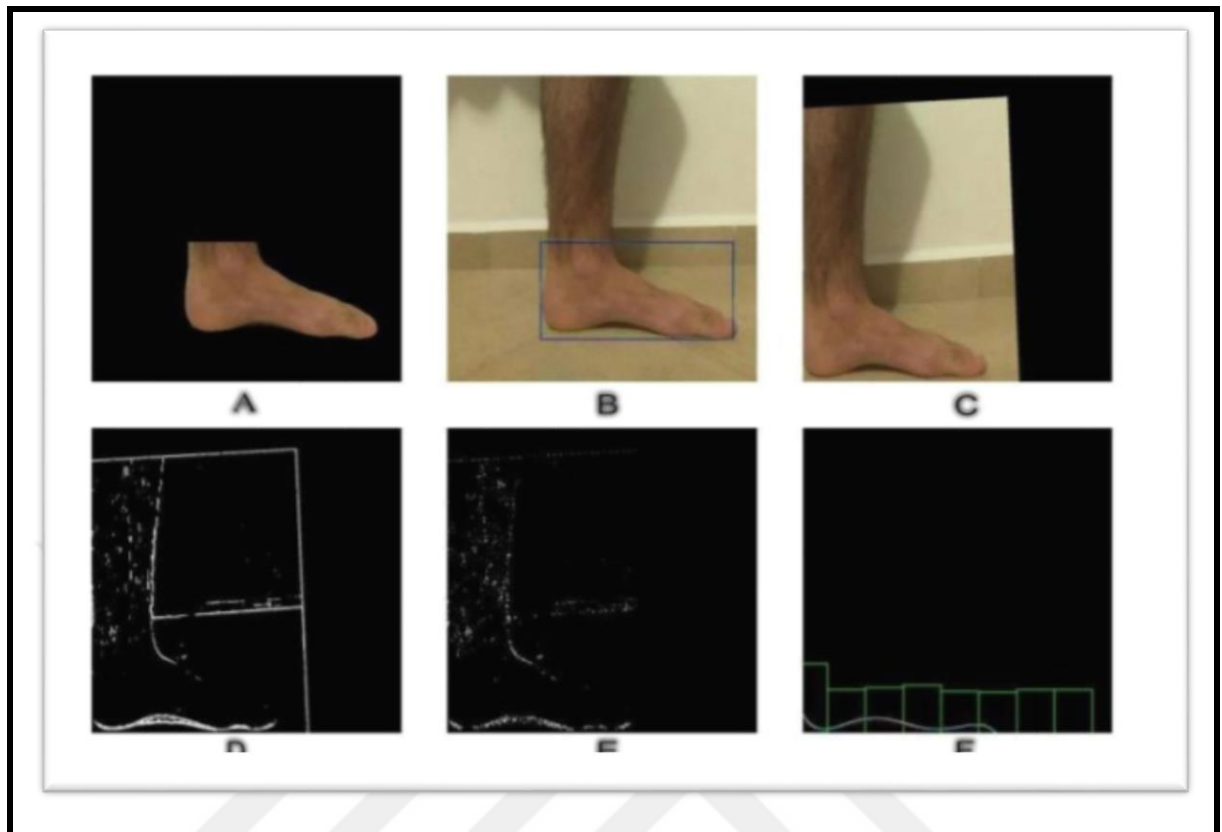


Figure 3.23. Foot deformity detection with ArdAyak app

**Data Analysis**

Statistical analyzes were applied by using IBM SPSS Statistics 22 Program. The Kolmogorov–Smirnov test was applied to assess the distribution of the data. Descriptive statistics were used to define features of study groups. To compare two independent groups with normal distribution, the Independent Sample-t" test (t-table value) statistics were utilized. Statistical analysis was performed pre intervention and 8th week evaluation for parametric data with Paired Sample T-test. To compare factors between the three separate groups, a one-way ANOVA was used. Pearson correlation coefficients were utilized to find significant correlations between the outcomes of two instruments. The 0.05 significance value was used.



## 4.RESULTS

The study included;

### I) Hind Foot Pain Patients

77 HP patients with 120 feet (PFs-28F/11M,  $49.26 \pm 10.22$  years; ATpathy-16F/22M,  $33.00 \pm 10.07$ ) admitted to Orthopedics and OsteoAcademy -Sonomed Medical Imaging Center

### II) Volunteers for Smart Phone Applications Pilot Studies

Total 36 subjects (72 feet) were volunteered for pilot studies.

- a) Twenty-two healthy university students with 44 feet (14 female and 8 male aged 18–24 years) for smartphone application –DijiA,
- b) Fourteen foot deformity patients with 28 feet (7 female and 7 male aged 21-29 years) for ArdAyak smartphone application.

Table 4.1. The number of feet in the study populations

|                    | Patient (N) | Foot (N) |
|--------------------|-------------|----------|
| <b>HP</b>          | 77          | 120      |
| <b>DijiA app</b>   | 22          | 44       |
| <b>ArdAyak app</b> | 14          | 28       |

HP: Hind foot Pain, App: application, N: number

### I)Hind Foot Pain Patients

Seventy seven HP patients with one hundred twenty feet (PFs-28F/11M,  $49.26 \pm 10.22$  years; ATpathy-16F/22M,  $33.00 \pm 10.07$ ) admitted to Orthopedics and OsteoAcademy -Sonomed Medical Imaging Center.

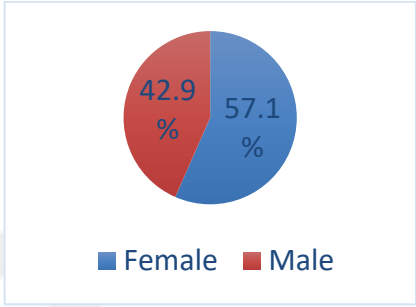
Table 4.2. The Abbrevation of the study groups

|                                                | <b>PFs</b> | <b>ATpathy</b> |
|------------------------------------------------|------------|----------------|
| <b>Conventional<br/>Physiotherapy Group</b>    | PFs-C      | ATpathy-C      |
| <b>Home Exercises<br/>Rehabilitation Group</b> | PFs-H      | ATpathy-H      |
| <b>Tele-rehabilitation Group</b>               | PFs-T      | ATpathy-T      |

PFs: Plantar Fasciitis, ATpathy: Achilles Tendinopathy.

The physical characteristics (age, weight, height, body mass index –BMI-, gender distribution) of the HP study group are presented in Table 4.3.

Table 4.3. The Physical Characteristic of the Hindfoot Pain Study Group

| <b>N (77)</b>                                      | <b>PFs &amp; ATpathy<br/>Mean± S.D.</b> | <b>PFs &amp; ATpathy<br/>Min-MAX</b>                                                |
|----------------------------------------------------|-----------------------------------------|-------------------------------------------------------------------------------------|
| <b>Age (years)</b>                                 | 41.23 ±12.98                            | 19-67                                                                               |
| <b>Gender %(n)</b><br><b>Female</b><br><b>Male</b> | 57.1(44)<br>42.9 (33)                   |  |
| <b>Height (m)</b>                                  | 1.68±.09                                | 1.50-1.87                                                                           |
| <b>Weight (kg)</b>                                 | 73.33±13.11                             | 49-116                                                                              |
| <b>BMI (kg/m²)</b>                                 | 25.91 ±5.47                             | 18-40                                                                               |

PFs: Plantar Fasciitis, ATpathy: Achilles Tendinopathy, N: Patient Number, BMI: Body Mass Index, m:metre, mo: month

The gender, laterality, BMI, age, weight, height, in the study groups according to pathologies were given in Table 4.4. Laterality showed that 53.8 percent of PFs were bilateral and 57.9 percent of ATpathy were bilateral.

Table 4.4. The Physical Characteristic of Patients with Plantar Fasciitis & Achilles Tendinopathy

| N                             | PFs (39)     | ATpathy(38) |
|-------------------------------|--------------|-------------|
| <b>Age (year)</b>             | 49.26 ±10.22 | 33.00±10.07 |
| <b>Gender %(n)</b>            |              |             |
| <b>Female</b>                 | 71.8(28)     | 42.1(16)    |
| <b>Male</b>                   | 28.2(11)     | 57.9(22)    |
| <b>Height(m)</b>              | 1.64±.08     | 1.72±.08    |
| <b>Weight (kg)</b>            | 78.17±11.46  | 68.36±12.96 |
| <b>BMI (kg/m<sup>2</sup>)</b> | 28.97 ±5.19  | 22.78±3.71  |
| <b>Symptom duration (mo)</b>  | 25.03±15.97  | 7.89±5.55   |
| <b>Laterality %(n)</b>        |              |             |
| <b>Left</b>                   | 28.2 (11)    | 18.4 (7)    |
| <b>Right</b>                  | 17.9 (7)     | 23.7 (9)    |
| <b>Bilateral</b>              | 53.8(21)     | 57.9(22)    |

PFs: Plantar Fasciitis, ATpathy: Achilles Tendinopathy, N: Patient Number, BMI: Body Mass Index, m:metre, mo: month

Paired t-test were used to compare the means of values for foot function index (FFI), visual analogue scale (VAS), and ankle range of motion for DF and PF scores with normal distribution interms of pre-post intervention (8th week). The findings showed that the means of DF, PF, FFI and VAS scores were improved at 8th week compared the results in pre intervention ( $p<.05$ , Table 4.5).

Table 4.5. The Comparison of The Foot Function Index (FFI) Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intragroup Variables in Plantar Fasciitis Patients

| PFs (N) |    | PFs-C (20)<br>Mean±S.D | t<br>P value | PFs-H (20)<br>Mean±S.D | t<br>P value | PFs-T (20)<br>Mean±S.D | t<br>P value |
|---------|----|------------------------|--------------|------------------------|--------------|------------------------|--------------|
| DF (°)  | T0 | 14.10±2.61             | -10.06       | 11.25±1.83             | -9.86        | 14.955±1.53            | -8.71        |
|         | T1 | 18.10±2.10             | <.01         | 13.50±1.96             | <.01         | 16.55±1.39             | <.01         |
| PF (°)  | T0 | 43.45±6.95             | -2.99        | 36.30±4.78             | -4.55        | 37.25±3.24             | -6.49        |
|         | T1 | 47.45±4.71             | <.01         | 37.90±4.56             | <.01         | 38.90±3.04             | <.01         |
| VAS     | T0 | 8.75±1.29              | 16.99        | 5.55±1.46              | 12.33        | 5.85±.93               | 7.57         |
|         | T1 | 2.85±1.53              | <.01         | 3.70±1.49              | <.01         | 3.50±1.23              | <.01         |
| FFI     | T0 | 72.22±10.56            | 16.63        | 50.02±15.83            | 10.26        | 64.34±11.00            | 6.82         |
|         | T1 | 29.91±13.12            | <.01         | 34.02±14.07            | <.01         | 33.89±15.26            | <.01         |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, N: Foot Number T0: pre-intervention, T1: 8th week evaluation, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion

The improvement of the findings for dorsiflexion, plantarflexion, VISA-A and VAS scores were illustrated in Table 4.6. We found the statistically significant improvements in dorsiflexion, plantarflexion, ROM measurements, VAS and VISA-A scores for 8th week evaluation in the Achilles Tendinopathy study groups ( $p<.05$ , Table 4.6).

Table 4.6. The Comparison of The Victorian Institute Of Sports Assessment – Achilles Questionnaire (VISA-A), Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intragroup Variables in Achilles Tendinopathy Patients

| ATpathy (N) |    | ATpathy-C<br>(20)<br>Mean±S.D | t<br>P<br>value | ATpathy-H<br>(20)<br>Mean±S.D | t<br>P<br>value | ATpathy-T<br>(20)<br>Mean±S.D | t<br>P<br>value |
|-------------|----|-------------------------------|-----------------|-------------------------------|-----------------|-------------------------------|-----------------|
| DF (°)      | T0 | 13.50±2.11                    | -7.19           | 15.80±3.39                    | -2.92           | 15.65±1.53                    | -8.04           |
|             | T1 | 18.20±1.88                    | <.01            | 16.90±2.82                    | <.01            | 17.90±1.58                    | <.01            |
| PF (°)      | T0 | 34.80±5.40                    | -9.03           | 37.70±5.71                    | -3.56           | 39.25±3.38                    | -6.24           |
|             | T1 | 41.60±3.85                    | <.01            | 41.95±5.04                    | <.01            | 41.75±2.63                    | <.01            |
| VAS         | T0 | 7.45±1.87                     | 12.25           | 5.90±1.77                     | 7.74            | 5.25±1.01                     | 20.14           |
|             | T1 | 2.35±1.87                     | <.01            | 2.85±1.72                     | <.01            | 1.95±.68                      | <.01            |
| VISA-A      | T0 | 47.75±9.80                    | -19.07          | 51.05±13.30                   | -11.18          | 47.10±9.80                    | -16.66          |
|             | T1 | 78.15±10.94                   | <.01            | 75.45±12.72                   | <.01            | 77.50±11.38                   | <.01            |

Data expressed as mean ±standard deviation, ATpathy: Achilles Tendinopathy, N: Foot Number T0: pre-intervention, T1: 8th week evaluation, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion

According to paired t-test, the findings showed that the means of Tampa Scale for Kinesiophobia (TSK) Scores were improved at post-intervention (8th week) comparing pre intervention in the study groups. ( $p < .05$ , Table 4.7).

Table 4.7. The Comparison of Tampa Scale for Kinesiophobia (TSK) Scores of Intragroup Variables

| <b>PFs (N)</b>     | <b>PFs-C<br/>(12)<br/>Mean±S.D</b>      | <b>t<br/>P value</b> | <b>PFs-H<br/>(13)<br/>Mean±S.D</b>      | <b>t<br/>P value</b> | <b>PFs-T<br/>(14)<br/>Mean±S.D</b>      | <b>t<br/>P value</b> |
|--------------------|-----------------------------------------|----------------------|-----------------------------------------|----------------------|-----------------------------------------|----------------------|
| <b>T0</b>          | 42.00±6.22                              | 6.82                 | 44.07±3.88                              | 2.57                 | 41.71±4.27                              | 8.32                 |
| <b>T1</b>          | 36.83±5.02                              | <.01                 | 41.15±3.60                              | <.01                 | 35.64±5.42                              | <.01                 |
| <b>ATpathy (N)</b> | <b>ATpathy-<br/>C (12)<br/>Mean±S.D</b> | <b>t<br/>P value</b> | <b>ATpathy-<br/>H (13)<br/>Mean±S.D</b> | <b>t<br/>P value</b> | <b>ATpathy-<br/>T (13)<br/>Mean±S.D</b> | <b>t<br/>P value</b> |
| <b>T0</b>          | 42.08±6.48                              | 3.34                 | 35.84±4.93                              | 3.22                 | 37.53±3.86                              | 7.61                 |
| <b>T1</b>          | 36.58±3.89                              | <.01                 | 32.61±2.39                              | <.01                 | 30.46±1.85                              | <.01                 |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, N: Patient Number, ATpathy: Achilles Tendinopathy, TSK: Kinesiophobia (TSK) Scores T0: pre-intervention, T1: 8th week evaluation, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion

Paired t-test was used to determine the differences in FAAM scores on pre intervention and 8th week. The results showed that the mean of FAAM Activities of Daily Living and Sports were increased in 8th week ( $p < .05$ , Table 4.8).

Table 4.8. The Comparison The Foot and Ankle Ability Measure (FAAM) Scores of Intragroup Variables

| N                  | PFs-T<br>(14) | t<br>P value | ATpathy-T<br>(13) | t<br>P value |
|--------------------|---------------|--------------|-------------------|--------------|
| <b>FAAM-ADL</b>    |               |              |                   |              |
| <b>T0</b>          | 51.35±11.04   | -8.65        | 68.61±4.92        | -9.41        |
| <b>T1</b>          | 72.50±5.47    | <.01         | 88.23±5.84        | <.01         |
| <b>FAAM-SPORTS</b> |               |              |                   |              |
| <b>T0</b>          | 32.35±9.14    | -6.15        | 58.30±7.75        | -6.81        |
| <b>T1</b>          | 47.42±7.95    | <.01         | 71.92±5.21        | <.01         |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, N: Patient Number, ATpathy: Achilles Tendinopathy, T0: pre-intervention, T1: 8th week evaluation, ADL: Activities of Daily Living.

One way ANOVA test was used to analyze in-group changes. Table 4.9 demonstrated that there were a statistical difference in dorsiflexion and plantar flexion ROM scores at post-intervention ( $p<.05$ ).

Table 4.9. The Comparison of The Foot Function Index (FFI) Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of post- intervention Intergroup Variables of Plantar Fasciitis Patients

| <b>PFs<br/>(N=60)</b> | <b>PFs-C (20)<br/>Mean±S.D</b> | <b>PFs-H (20)<br/>Mean±S.D</b> | <b>PFs-T (20)<br/>Mean±S.D</b> | <b>F<br/>P value</b> |
|-----------------------|--------------------------------|--------------------------------|--------------------------------|----------------------|
| <b>DF (°)</b>         | 18.10±2.10                     | 13.50±1.96                     | 16.55±1.39                     | 32.22<br><.01        |
| <b>PF (°)</b>         | 47.45±4.71                     | 37.90±4.56                     | 38.90±3.04                     | 31.58<br><.01        |
| <b>VAS</b>            | 2.85±1.53                      | 3.70±1.49                      | 3.50±1.23                      | 1.94<br>.15          |
| <b>FFI</b>            | 29.91±13.12                    | 34.02±14.07                    | 33.89±15.26                    | .54<br>.29           |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, N: Foot Number, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion, FFI: Foot Function Index, VAS: Visual Analog Scale.

According to ANOVA test results in Table 4.10. there were no difference among group means of Post-Treatment VISA-A, VAS and Ankle ROM scores in Achilles Tendinopathy patients(  $p>0.05$ ).

Table 4.10. The Comparison of Post-Treatment The Victorian Institute Of Sports Assessment – Achilles Questionnaire (VISA-A), Visual Analogue Scale (VAS) and Ankle Range of Motion (ROM) Scores of Intergroup Variables of Achilles Tendinopathy Patients

| <b>ATpathy<br/>(N=60)</b> | <b>ATpathy-C<br/>(20)<br/>Mean±S.D</b> | <b>ATpathy-H<br/>(20)<br/>Mean±S.D</b> | <b>ATpathy-T<br/>(20)<br/>Mean±S.D</b> | <b>F<br/>P value</b> |
|---------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------|
| <b>DF (°)</b>             | 18.20±1.88                             | 16.90±2.82                             | 17.90±1.58                             | 1.98<br>.14          |
| <b>PF (°)</b>             | 41.60±3.85                             | 41.95±5.04                             | 41.75±2.63                             | .039<br>.96          |
| <b>VAS</b>                | 2.35±1.87                              | 2.85±1.72                              | 1.95±.68                               | 1.75<br>.18          |
| <b>VISA-A</b>             | 78.15±10.94                            | 75.45±12.72                            | 77.50±11.38                            | .29<br>.75           |

Data expressed as mean ±standard deviation, ATpathy: Achilles Tendinopathy, N: Foot Number, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion

The one-way analysis of variance (ANOVA) test and Tukey post-hoc was used to analyze in-group changes. Table 4.11 showed that there was a statistical difference in Tampa Scale for Kinesiophobia (TSK) Scores for both pathologies at 8<sup>th</sup> week ( $p < .05$ ).

Table 4.11. The Comparison of Post-treatment Tampa Scale for Kinesiophobia (TSK)  
Scores of Inter-group Variables

| <b>PFs<br/>(N=39)</b>     | <b>PFs-C (12)<br/>Mean±S.D</b>         | <b>PFs-H (13)<br/>Mean±S.D</b>         | <b>PFs-T (14)<br/>Mean±S.D</b>         | <b>F<br/>P value</b> |
|---------------------------|----------------------------------------|----------------------------------------|----------------------------------------|----------------------|
| <b>TSK</b>                | 36.83±5.02                             | 41.15±3.60                             | 35.64±5.42                             | 4.90<br><.01         |
| <b>ATpathy<br/>(N=38)</b> | <b>ATpathy-C<br/>(12)<br/>Mean±S.D</b> | <b>ATpathy-H<br/>(13)<br/>Mean±S.D</b> | <b>ATpathy-T<br/>(13)<br/>Mean±S.D</b> | <b>F<br/>P value</b> |
| <b>TSK</b>                | 36.58±3.89                             | 32.61±2.39                             | 30.46±1.85                             | 15.09<br><.01        |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, ATpathy: Achilles Tendinopathy, N: Patient Number, TSK: Kinesiophobia (TSK) Scores.

The one-way analysis of variance (ANOVA) test and Tukey post-hoc was used to analyze in-group changes. Table 4.12 demonstrated that there were a statistical differences in Tampa Scale for Kinesiophobia (TSK) and VAS Scores for both pathologies at 8<sup>th</sup> week evaluation ( $p<.05$ ).

Table 4.12. The Comparison of Post-treatment Tampa Scale for Kinesiophobia (TSK) Scores and Visual Analogue Scale (VAS) of Inter-group Variables

| <b>Groups<br/>(N)</b> | <b>PFs-C<br/>(12)<br/>Mean±<br/>S.D</b> | <b>PFs-H<br/>(13)<br/>Mean±<br/>S.D</b> | <b>PFs-T<br/>(14)<br/>Mean±<br/>S.D</b> | <b>ATpath<br/>y-C<br/>(12)<br/>Mean±<br/>S.D</b> | <b>ATpath<br/>y-H<br/>(13)<br/>Mean±<br/>S.D</b> | <b>ATpath<br/>y-T<br/>(13)<br/>Mean±<br/>S.D</b> | <b>F/P</b>    |
|-----------------------|-----------------------------------------|-----------------------------------------|-----------------------------------------|--------------------------------------------------|--------------------------------------------------|--------------------------------------------------|---------------|
| <b>TSK</b>            | 36.83±<br>5.02                          | 41.15±<br>3.60                          | 35.64±<br>5.42                          | 36.58±<br>3.89                                   | 32.61±<br>2.39                                   | 30.46±<br>1.85                                   | 11.54<br><.01 |
| <b>VAS</b>            | 2.85±<br>1.53                           | 3.70±<br>1.49                           | 3.50±<br>1.23                           | 2.35±<br>1.87                                    | 2.85±<br>1.72                                    | 1.95±.<br>68                                     | 4.05<br><.01  |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, ATpathy: Achilles Tendinopathy, N: Patient Number, TSK: Kinesiophobia (TSK) Scores, VAS: Visual Analog Scale.

An independent sample t-test was performed to compare foot and ankle ability measure scores baseline study variables between two groups. The datas indicated that there were statistical significance in terms of FAAM-ADL, FAAM-SPORTS ( $p<.05$ , Table 4.13).

Table 4.13. The Comparison The Foot and Ankle Ability Measure (FAAM) Scores of Intergroup Variables

| <b>N=27</b>        | <b>PFs-T (14)<br/>Mean±S.D</b> | <b>ATpathy-T (13)<br/>Mean±S.D</b> | <b>t<br/>P value</b> |
|--------------------|--------------------------------|------------------------------------|----------------------|
| <b>FAAM-ADL</b>    | 72.50±5.47                     | 88.23±5.84                         | -7.21<br><.01        |
| <b>FAAM-SPORTS</b> | 47.42±7.95                     | 71.92±5.21                         | -9.37<br><.01        |

Data expressed as mean ±standard deviation, PFs: Plantar Fasciitis, N: Patient Number, ATpathy: Achilles Tendinopathy, ADL: Activities of Daily Living.

## II) Volunteers for Smart Phone Applications Pilot Studies

- a) Healthy university students for smartphone application –DijiA were included.*
- b) Foot deformity patients for smartphone application-ArdAyak were admitted.*

DijiA pilot study participants' descriptive data (age, weight, and height) are presented in Table 4.14.

Table 4.14. DijiA Pilot Study Participants' Descriptive Data

| <b>N=22</b>        | <b>Minimum</b> | <b>Maximum</b> | <b>Mean ±SD</b> |
|--------------------|----------------|----------------|-----------------|
| <b>Age (years)</b> | 18             | 24             | 20.68±1.72      |
| <b>Height (cm)</b> | 157            | 183            | 170.27±9.21     |
| <b>Weight (kg)</b> | 47             | 91             | 65.09±14.52     |

N: Patient Number, cm: centimetre, kilogram

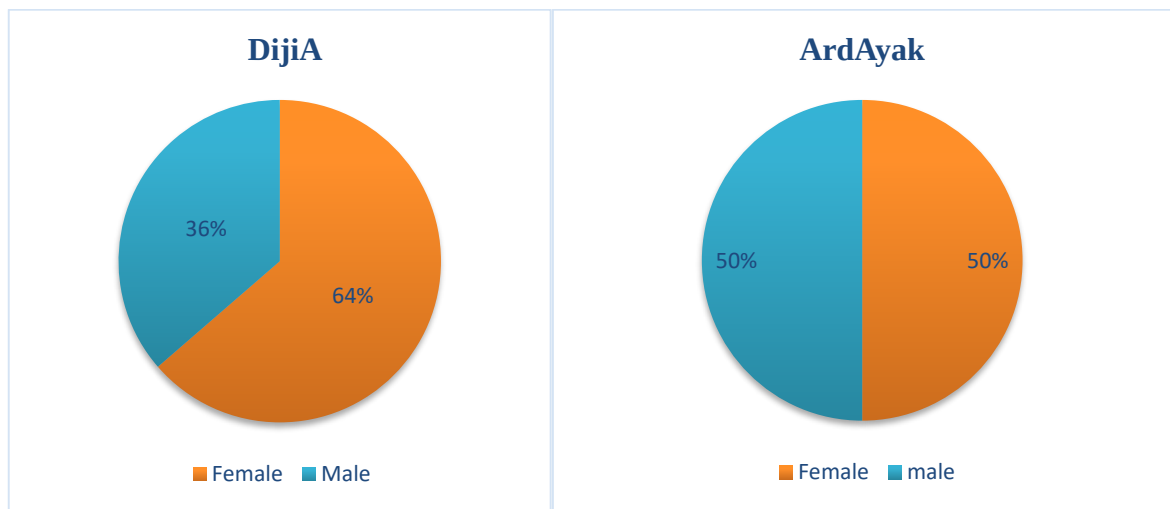
ArdAyak app pilot study participants' descriptive data (age, weight, and height) are presented in Table 4.15.

Table 4.15. ArdAyak App Pilot Study Participants' Descriptive Data

| <b>N=14</b>        | <b>Minimum</b> | <b>Maximum</b> | <b>Mean <math>\pm</math>SD</b> |
|--------------------|----------------|----------------|--------------------------------|
| <b>Age (years)</b> | 21             | 29             | 22.14 $\pm$ 2.17               |
| <b>Height (cm)</b> | 159            | 191            | 172.28 $\pm$ 11.53             |
| <b>Weight (kg)</b> | 50             | 100            | 66.85 $\pm$ 17.19              |

N: Patient Number, cm: centimetre, kilogram

The Gender distribution was showed in Figure 4.1. While totally 64 percent of Dijia pilot study participants were female, the total distribution of female were 50 percent in ArdAyak app pilot study participant (Figure 4.1).



Data expressed as % .

Figure 4.1.The Distribution of Gender

For comparing the universal goniometer (UG) and Dijia, 44 feet were available in Table 4.16. The mean of ROM measured with the UG were DF for  $19.93 \pm 8.00$ , PF for  $38.59 \pm 6.46$  and measured with the Dijia were DF for  $37.45 \pm 29.52$ , PF for  $78.55 \pm 56.54$ .

Table 4.16. Summary Statistics For Ankle Range of Motion (ROM) Measurements In The Study Participants

| ROM (N=44)          | Minimum | Maximum | Mean $\pm$ SD     |
|---------------------|---------|---------|-------------------|
| <b><u>UG</u></b>    |         |         |                   |
| <b>DF</b>           | 10.00   | 50.00   | 19.93 $\pm$ 8.00  |
| <b>PF</b>           | 25.00   | 50.00   | 38.59 $\pm$ 6.46  |
| <b><u>DijiA</u></b> |         |         |                   |
| <b>DF</b>           | 0.00    | 88.23   | 37.45 $\pm$ 29.52 |
| <b>PF</b>           | 0.00    | 235.65  | 78.55 $\pm$ 56.54 |

Data expressed as mean  $\pm$  standard deviation, N: Foot Number, ROM: Range of Motion, DF: Dorsiflexion, PF: Plantar Flexion, UG: Universal Goniometer, DijiA: Dijital Adımlar App

According to Pearson Correlation Coefficient between the universal goniometer (UG) and the DijiA in measuring ankle dorsiflexion and plantarflexion were significant with DF; 95 percent IC=.06-.65; PF; 95 percent IC= .21-.64 (Table 4.17,  $p < 0.05$ ).

Table 4.17. Pearson Correlation Coefficient Between the Universal Goniometer and Dijia Smartphone App

| ROM            | Pearson Correlation | %95 CI    | P value |
|----------------|---------------------|-----------|---------|
| DF<br>UG-DijiA | .323                | (.06-.65) | <.01    |
| PF<br>UG-DijiA | .435                | (.21-.64) | <.01    |

Abbreviations: CI: confidence interval, DF: Dorsiflexion, PF: Plantar Flexion, UG: Universal Goniometer, DijiA: Dijital Adımlar App

The variation in Pearson Correlation Coefficient Between the Universal Goniometer and Dijia Smartphone App result was showed in Figure 4.2. According to these findings, there was a moderate positive relationship Between the Universal Goniometer and Dijia (  $r=.323$  for DF,  $r=.435$  for PF, Figure 4.2).



Figure 4.2. Pearson Correlation Coefficient Relationship Between the Universal Goniometer and Dijia Smartphone App

The System Usability Scale (SUS) is a 10 item questionnaire with 5 response options (Appendix C). The Survey results for measuring usability of DijiaA smartphone app were displayed in Table 4.18. In the literature, A SUS score of 68 or more is regarded above average, while anything below 68 is considered below standard. SUS score was report as 76.5 (higher perceived usability). It can be interpreted that the application usability is high and people liked it (Table 4.18).



Table 4.18. Distribution of Answers to the System Usability Scale (SUS) Survey  
Questionnaire for Dijia Smartphone App

| <b>Questions</b>                     | <b>Disagree<br/>%(n)</b> | <b>Not sure<br/>%(n)</b> | <b>Agree<br/>%(n)</b> |
|--------------------------------------|--------------------------|--------------------------|-----------------------|
| <b>Complexity</b>                    | 86.6 (13)                | 6.6 (1)                  | 6.6 (1)               |
| <b>Ease of use</b>                   |                          | 6.6 (1)                  | 93.33 (14)            |
| <b>Technical support<br/>need</b>    | 66.6 (10)                | 20 (3)                   | 13.33 (2)             |
| <b>Integration of<br/>functions</b>  | 6.6 (1)                  | 13.33 (2)                | 80 (12)               |
| <b>Presence of<br/>inconsistency</b> | 93.33 (14)               | 6.6 (1)                  |                       |
| <b>Quick use</b>                     |                          | 20 (3)                   | 80 (12)               |
| <b>App is slow</b>                   | 80 (12)                  | 20 (3)                   |                       |
| <b>Confident Use</b>                 |                          | 20 (3)                   | 80 (12)               |
| <b>learn before use</b>              | 66.6 (10)                | 26.66 (4)                | 6.6 (1)               |

The overall score given by the participants to the application was recorded by evaluating it out of 10, and the average was found to be 8.26. In addition, feedback was received from the participants expressing their opinions and suggestions for the application. Accordingly, 3 people out of 15 gave the feedback which is written in the Table 4.19.

Table 4.19. The Application Overall Score, Suggestions and Feedback Results for Dijia Smartphone App

| Application Overall Score<br>(N=15)<br>[minumum-maximum] | Feedbacks<br>(N=3)                                                                                                                               |
|----------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| [0-10]<br>Total=124<br>Mean=8.26                         | Video upload locations can be improved.<br>The purple color used in the interface may be a different choice.                                     |
|                                                          | very good                                                                                                                                        |
|                                                          | We didn't understand much. It took a short time to meet with the application, but I think it will make our work easier in the future, thank you. |

The mean SD, minimum and maximum values of shoe size, morning, activity and night pain for foot deformity detection in the study participants are presented in Table 4.18. The mean pain scores of morning was  $.17 \pm .66$ ; activity was  $1.03 \pm 1.68$  (Table 4.20).

Table 4.20. Summary Statistics For ArdAyak App Pilot Study Participants

| <b>ROM (N=28)</b>    | <b>Minimum</b> | <b>Maximum</b> | <b>Mean <math>\pm</math>SD</b> |
|----------------------|----------------|----------------|--------------------------------|
| <b>Morning Pain</b>  | .00            | 3.00           | .17 $\pm$ .66                  |
| <b>Activity Pain</b> | .00            | 5.00           | 1.03 $\pm$ 1.68                |
| <b>Night Pain</b>    | .00            | .00            | .00                            |
| <b>Shoe size</b>     | 36             | 46             | 41.07 $\pm$ 8.49               |

Data expressed as mean  $\pm$ standard deviation, N: Foot Number.

The comparison of foot deformity distribution numbers according to measurements device (sidas- custom station premium and ardayak smartphone app) was showed in Table 4.21.

Table 4.21. A Comparison of Foot Deformity Distribution Between the SIDAS- custom station Premium and ArdAyak Smartphone App

| Characteristic<br>N=28 | Sidas<br>(n) | App<br>(n) |
|------------------------|--------------|------------|
| <b>Pes cavus</b>       | 8            | 6          |
| <b>Pes Planus 1</b>    | 10           | 11         |
| <b>Pes Planus 2</b>    | 8            | 7          |
| <b>Pes Planus 3</b>    | 2            | 2          |
| <b>Unknown</b>         | 0            | 2          |

Abbreviations: CI: confidence interval, DF: Dorsiflexion, PF: Plantar Flexion, UG: Universal Goniometer, Dijia: Dijital Adımlar App

Measurement data percentage from SIDAS- custom station Premium for analysis of foot deformation was reported in Figure 4.3. While the percentage of 1st degree pes planus was 36, the percentage of pes cavus was found to be 29 percent.

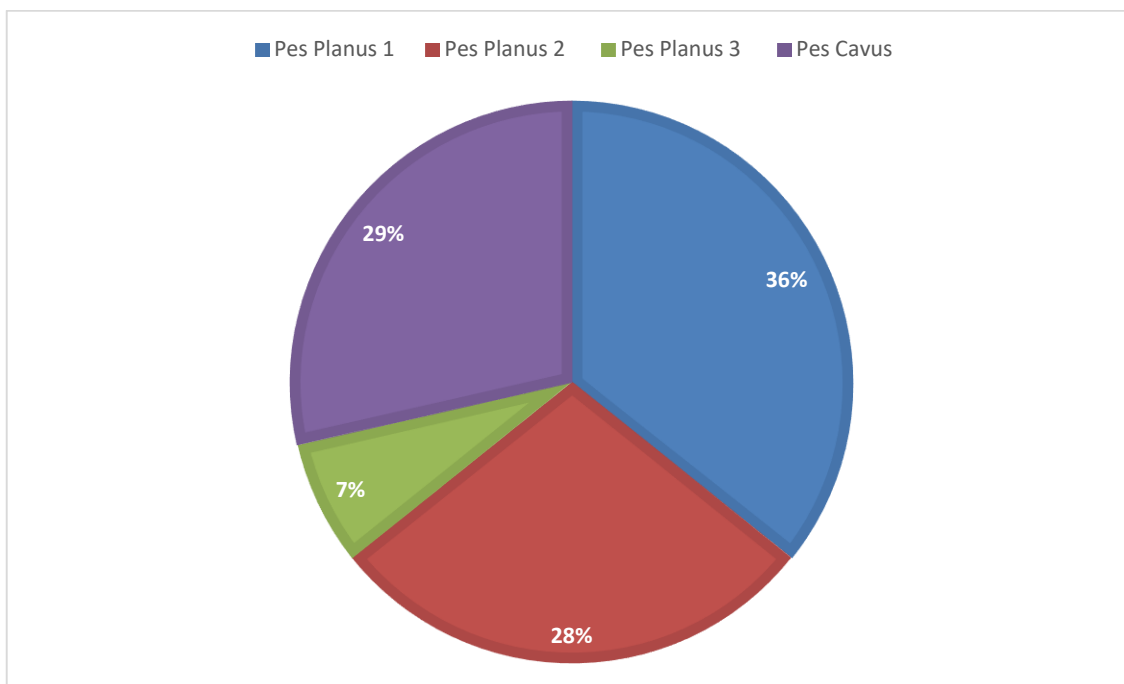


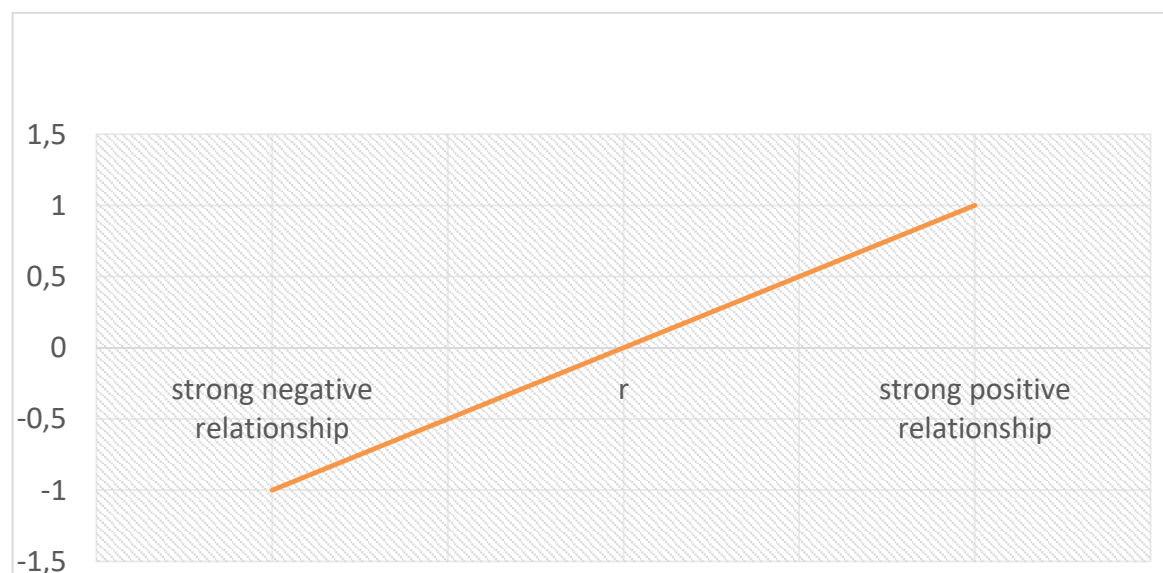
Figure 4.3. Distribution of Foot Deformity Diagnosis in SIDAS- custom station Premium

Concurrent validity which determines the instrument performance was assessed between sidas- custom station premium and Ardayak smartphone app using the Pearson correlation coefficient ( $r$ ). Pearson correlation coefficient can vary between -1 and +1. According to findings, there was a significant correlation between the the sidas- custom station premium and Ardayak smartphone app measurements (Table 4.22,  $p < 0.05$ ). Furthermore, analysis showed moderate correlations among the the sidas- custom station premium and Ardayak smartphone app with  $r$  values of 0.468, for foot deformity (moderate direct relationship) (Figure 4.4).

Table 4.22. Pearson Correlation Coefficient Between the SIDAS- custom station Premium and ArdAyak Smartphone App

| N=28              | Pearson Correlation | %95 CI    | P value |
|-------------------|---------------------|-----------|---------|
| Sidas-ArdAyak app | .468                | (.07-.86) | <.01    |

Abbreviations: CI: confidence interval



Abbreviations: CI: confidence interval, DF: Dorsiflexion, PF: Plantar Flexion, UG: Universal Goniometer, DijitA: Dijital Adımlar App

Figure 4.4. Pearson Correlation Coefficient Relationship Between the SIDAS- custom station Premium and ArdAyak Smartphone App

## 5. DISCUSSION

Hindfoot pain can appear in the heel and the medial, posterior and anterior ankles [12]. According to a meta-analysis of studies, the prevalence of this pain among older individuals ranges from 4 to 20 percent [1]. Generally, patients with HP treatment is applied for its two anatomic structures: the PFa and the AT. According to the literature, it can be said that the significant pathologies that cause HP are PFs and ATpathy [11, 28, 103]. PFs is one of the most frequent hindfoot issues, generating discomfort on the plantar side of the hindfoot, especially at the inferior-medial heel, and accounting for 11–15 percent of all foot complaints requiring professional attention [82, 90]. Accounts for over one million outpatient visits per year in the US, and estimates are that 10 percent of all adults will develop PFs at some time [80]. Furthermore, 43 percent of elite athletes said they have ATpathy symptoms now or in the past, with middle-distance runners having the greatest rate (83 percent). ATpathy, on the other hand, isn't only an athletic problem, since 65 percent of injuries identified in a general practice setting aren't related to sports. [92, 94]. In clinical practice, there are several physiotherapy interventions in pathology-based approaches; however, clinical consensus for combined treatment methods of HP is insufficient [11].

Physiotherapeutic treatment modalities have been proposed to decrease pain and improvement of function for PFs, including low-level laser, iontophoresis, phonophoresis, ESWT, taping, appropriate footwear and biomechanic support, myofascial releasing orthotic devices, corticosteroid injection, PRP, joint and soft tissue mobilization [86, 90, 110]. In a single-blind RCT, the benefits of stretching with or without muscle strengthening of the foot alone or the foot and hip on pain and function in PFs patients were compared by Kamonseki et al. for eight weeks, eighty-three PFs patients were randomized to one of three treatment groups at random: Stretching Alone (extrinsic-intrinsic foot muscles), Foot- Hip (abductor, lateral rotator muscles), and Foot-Hip Exercise Groups (abductor, lateral rotator muscles). VAS, pain, activities of daily living, sports and recreation, quality of life ( $p < .00$ ) and other symptoms ( $p < .01$ ) subscales of the Foot and Ankle Outcome Score, as well as the Star Excursion Balance Test total score ( $p < .00$ ) all improved in three groups, according to their findings [175]. In systematic review and meta-analysis conducted by Siriphorn and Eksakulkla, two stretching techniques effectiveness and efficacy (A calf stretching (CS) and a plantar fascia-specific stretching (PFSS)) in the PFs treatment were

investigated. It was reported that when CS and PFSS were compared there was evidence of intermediate quality that PFSS therapy reduced pain scores more than CS treatment ( $p < .05$ ). In contrast, extremely low-quality data suggested that a combination of CS and PFSS, or just CS, was better than sham stretching ( $p < .05$ ) [176]. Additionally, Yelverton et al. compared a) the manipulation of the foot with cross friction massage of the PFa, b) cross friction massage of the PFa with gastro-soleus complex stretching, c) a combination of the protocols mentioned earlier in the treatment of PFs. Forty-five volunteers were allocated into these three groups and received one of the proposed interventions. The ankle ROM and pain perception, FFI score and algometer were evaluated. The results indicated that PFa with stretching of the gastro-soleus complex showed significant improvement in reducing the pain, disability and DF ( $p < .05$ ) [177]. In the systematic review by Piper et al. searched six databases from 1990 to 2015, and they found that myofascial release (MFR) had superior effect in terms of pain revealing for PFs patients ( $p < .05$ ) [178]. Munir et al. studied the effectiveness of Mulligan's mobilization techniques for PFs. Thirty patients were included in their rehabilitation programme to receive manual mobilization. The study's data reported that all domains of FFI had significant differences after four weeks of session, except limited physical activities and the mulligan's mobilization techniques were useful in improving pain ( $p < .05$ ) [179]. A randomized controlled trial conducted by Kang et al. reported the effects of combined two interventions; a) gastrocnemius stretching with joint mobilization, b) gastrocnemius stretching. Twenty four patients with limited DF were allocated into gastrocnemius stretching with mobilization or just gastrocnemius stretching with 5 min. Ankle kinematics during gait, DF, talar glide to posterior, and myotendinous junction displacement of the gastrocnemius were evaluated pre-post interventions. In the stretching combination with mobilization group, there was a higher improvement in the time to heel-off and ankle DF before heel-off during locomotion, as well as posterior talar glide. Both groups' ankle DF and gastrocnemius MTJ displacement grew significantly following the therapies, with no significant differences between them ( $p > .05$ ) [180]. The main results of our study are that all PFs groups (PF-C, PF-H, PF-T) had statistically significant improvement in measurements of ROM (DF&PF), VAS, FFI and TSK scores at post intervention. ( $p < .05$ , Table 4.5, Table 4.7). Group PF-T had also greater improvement at post intervention in terms of FAAM-ADL and SPORTS scores ( $p < .05$ , Table 4.8). Additionally, conventional physiotherapy programs applied by physiotherapists involving mulligan concepts manual therapy, myofascial releasing, foot and ankle stretching and strengthening

exercises can lead to greater improvement in terms of DF and PF-ROM compared with other groups ( $p < .05$ , Table 4.9). The means of the post intervention TSK scores for the home-based exercises group were higher than comparing the tele-rehabilitation group ( $p < .05$ , Table 4.11). We can conclude that the Mulligan concept manual therapy, myofascial releasing, stretching and strengthening exercises are advised to incorporate into the management program for patients with PFs. Given the exercises programme, tele-rehabilitation (smartphone and web-based) can be considered effective and a better option for specifically reducing kinesiophobia scores.

The other common pathology of HP is ATpathy which typically reveals warmth, tenderness, thickness, and sometimes swelling. Many therapies, either in conjunction with exercise or in isolation, have been proposed to aid in the healing process. Rest, stretching-strengthening exercises, manual therapy, shoe adjustments, non-steroidal anti-inflammatory drugs, steroid injections, low-level laser therapy, topical glyceryl trinitrate patches, and several shoe modification procedures are examples of conservative therapies [92, 105]. Nonetheless, gradual tendon loading is still the most effective therapy [101, 105]. Yu et al. found that eccentric strengthening is more helpful than concentric in lowering pain and enhancing function in ATpathy patients ( $p < .05$ ) [181]. Moreover, in a study by Stasinopoulos, Alfredson protocol was found as superior to the Stanish model ( $p < .05$ ) [182]. While the Alfredson protocol's effectiveness is well-known, these studies are diverse since, even if it could be standardized, it is frequently weakened by progressively selective exercises. Verrell et al., for instance, adapted Alfredson's protocol to include bodyweight loading for at least 15 to 20 seconds during a six week period. They reported a significant decrease in discomfort and a high level of efficiency ( $p < .05$ ) [183]. According to literature, two case reports evaluated joint mobilization and manipulation in ATpathy. Jayaseelan et al. performed one of them, describing impairment-based joint mobilization, self-mobilization, and exercise. For enhancing his capacity to run and reducing symptoms, a 51-year-old man was given joint-based non-thrust and self-mobilization exercises. After 2 months, he demonstrated clinically significant improvements on the FAAM and VISA-A tests ( $p < .05$ ). At a one-year follow-up, the improvements were still there ( $p < .05$ ) [184]. The other one realized by Jayaseelan et al. and they prescribed joint mobilization and manipulation, eccentric loading and calf stretching exercises for three runners. Each patient had significant improvement of self-reported function on pain levels, VISA-A, and joint mobility ( $p < .05$ ). It can be concluded that MT might enhance the rehabilitation for ATpathy patients [185]. In

another research by McCormack et al., ATpathy patients were administered with soft tissue treatment with eccentric exercise and eccentric exercise alone and assessed at baseline, 4, 8, 12, 26, and 52 weeks. The results showed that significantly more significant improvements on the VISA-A in Astym group over the 12-week period ( $p < .05$ ). At the follow-ups of 26 and 52-week, the discrepancies maintained. Over the short and long term, both groups experienced statistically significant pain reduction ( $p < .05$ ). Soft tissue treatment mixed with eccentric exercise was shown to be more effective in improving function than eccentric exercise alone ( $p < .05$ ) [186]. Somers et al. also investigated whether a single app of the intervention of self-myofascial release on triceps surae with a foam roller, multiplanar dynamic stretch performed downward dog, or a combination of both modalities improved ankle DF. Both treatments were used for 1 minute each time. The weight-bearing right ankle DF measures of forty two asymptomatic physical therapy students were measured in cm using a forward lunge technique ( $r = .98, .97$ , and  $.96$ ). The post-measurement data analysis showed no significant differences between these three groups ( $P = .82$ ) [187]. Hasani et al. aimed to report the experience of participants and physiotherapists with gym-based exercise interventions for ATpathy monitored throughout videoconference. They conducted interviews with eight people and held seven physiotherapists. All participants were asked about their experiences with telehealth during a gym-based exercise program that included various calf load parameters for ATpathy. All participants found a gym-based exercise programme with weekly telehealth monitoring to be satisfactory. To enhance adherence to this sort of intervention, certain facilitators and impediments were identified [188]. In our research, it can be concluded that ROM for DF and PF measurements, VAS, VISA-A and TSK scores in all AT groups (AT-C, AT-H, AT-T) were improved at post intervention ( $p < .05$ , Table 4.6, Table 4.7). However, there were no statistical differences among all groups in terms of ROM, VAS and VISA-A ( $p > .05$ , Table 4.10). Moreover, we found that the AT-C group had a better TSK score than AT-H and AT-T ( $p < .05$ , Table 4.11). When comparing pre and post intervention FAAM Scores in AT-T, it was found that the statistically significant difference in FAAM-ADL and FAAM-SPORTS scores at eight weeks ( $p < .05$ , Table 4.8). We recommended that using mulligan concepts manual therapy, myofascial releasing, foot and ankle stretching and strengthening exercises as combined AT management to increase function and decrease pain. Furthermore, it can be indicated that applying for the exercises programme by smartphone enabled and web-based tele-rehabilitation systems for AT is effective.

Hindfoot pain, mostly associated with chronic medical problems (osteoarthritis, diabetes mellitus, e.g.), anatomical (pes planus-cavus), more excellent shoe wear, prolonged standing on hard surfaces, sports activity, and biomechanical (increased pronation subtalar joint, AT tightness, limited dorsi-plantar flexors weakness) factors [11, 68, 81, 96]. Early detection and evaluation of the risk factors of HP can effectively lead to control and prevent these symptoms and their chronicity [10, 11]. There are many manual and device-based tools in the literature for the early detection and evaluation of these risk factors mentioned above (especially foot deformity and ankle-ROM). For determination of ankle joint mobility, many tools can be used, such as tape measures, digital gravity goniometers, visual estimation, inclinometers, or measurement of joint angles after radiographic visualization in maximum flexion or extension, universal goniometers (UG) [163, 164]. Using visual evaluation or mechanical goniometers is inexpensive, easy and fast to perform but includes significant inaccuracy. Radiographic evaluation's increased exposure prohibits it from being widely used, yet it is widely acknowledged as the reference procedure [103, 166]. Other ROM measuring methods (gait analysis, digital goniometers, or imaging with computer image processing) are too time-consuming and costly to be used on a regular basis. Additionally, the UG is low-cost and extensively utilized [163, 166]. When Munteanu et al. evaluated ankle joint DF in a weight-bearing posture with the knee extended, they discovered that UG reliability (ICC  $\frac{1}{4}$  0.65–0.89) was worse than digital inclinometer (ICC  $\frac{1}{4}$  0.88) and acrylic plate apparatus dependability. (ICC  $\frac{1}{4}$  0.89) in previous research. [189]. Furthermore, Venturini et al. discovered that UG is simple to use and inexpensive; investigations have revealed that goniometric results by various examiners are inconsistent [190]. Despite this flaw, UG is still the gold standard for evaluating ROM in clinical practice. Some researchers utilized goniometers using dedicated hardware or mobile apps [132, 167, 189, 191, 192]. Furthermore, due of their accessibility, cost, and simplicity, numerous mobile applications on smartphones are increasingly being used in medical instead of traditional measuring equipment such as UG [193]. In earlier research, the validity and reliability of many smartphone ROM measurement apps were investigated, and they were found to be valid and reliable in measuring ROM in a variety of joints (elbow, knee, and fifth metatarsophalangeal joints).[14, 164]. The measurement intra/inter-rater reliability with knee exten-flexed was found as excellent, according to Williams et al., who investigated ankle DF-ROM in weight-bearing using the mobile goniometer app TiltMeter downloaded on a smartphone (ICC 0.8 or more) [167]. Two further studies that looked into the use of IOS-based goniometer apps

to assess weight-bearing DF-ROM found moderate to outstanding reliability and validity [191, 192]. Weight-bearing DF-ROM assessment utilizing the mobile goniometer software Spirit Level Plus loaded on an Android smartphone had reasonable inter/intra-rater reliability [194]. Why their reliabilities were higher might be explained in a number of ways. Using separate mobile goniometer applications on a different sort of device with a different operating system is the most obvious one that has been documented (Android versus iOS) [167]. Another is that apps may impact measurement disparities, and their individual software platforms must be thoroughly tested. Any new version of the app that becomes available should be re-validated [164, 195].

The weight-bearing ankle-ROM measures are still limited in that they cannot be utilized if weight-bearing is prohibited, and the process seems less objective than the nonweight-bearing one since the applied load is needed to attain the end position [189, 196]. Cox et al. studied the measurements of the ankle joint PF-ROM in non-weight-bearing position, and reported that The Plaincode Smartphone app was a valid instrument for measuring PF-ROM (right foot  $r = .92, p < .00$ , left foot  $r = .92, p < .00$ , combined  $r = .92, p < .00$ ) [197]. Furthermore, Walaa et al. examined the validity and intra-rater reliability of smartphone app “Clinometer” for measuring ankle ROM in non-weightbearing position using the digital inclinometer as the reference standard. It was found that Clinometer demonstrated moderate validity comparing with the digital inclinometer for ankle ROM ( $r = 0.52-0.57$ ) [198]. Similarly, in our study, pearson correlation between UG and Dijia was found to be moderate level ( $r = .323, p < .03$  for DF;  $r = .435, p < .00$  for PF, Table 4.17, Figure 4.2). Additionally, a SUS score was reported as higher perceived usability with 76.5 total average usability score (Table 4.18).

There are several ways for evaluate the foot deformity (pes planus-cavus) such as clinical evaluation, somatometric measurement, radiologic and ultrasonographic reviews. Additionally, inked or digital pressure foot-prints and photographic indirect techniques are also mentioned in the literature [199–202]. The most accepted and widely used detection method seems the radiological evaluation. The radiographic evaluation increased exposure prohibits it from being widely used, yet it is widely acknowledged as the reference procedure [203]. Chen et al. compared the arch index and radiological results of 103 individuals' navicular and talar heights and reported Chippaux-Smirak index, Clarke's angle, Staheli arch index respectively have 90.54, 83.89, and 85.43 percent prediction probability in preschool-

aged children ( $p < .05$ ) [204]. Additionally, Pauk et al. compared Clarke angle and radiography measurements of sixty children and found a correlation between radiography and footprint method ( $p < .05$ ). Additionally, many studies have searched the correlation between radiography and footprint methodologies [205]. Kanatli et al. investigated radiologic measurements and footprint methods and it was determined that there was a correlation between these two methods with 38 pre-schoolers and school-aged children with the average age of 6.4 (ages ranging between 3.7–11.7) and correlation between arch index, talo–first metatarsal, and talo–horizontal angle ( $p < .05$ ). On the other hand, they found non-significant correlation between arch index, calcaneal pitch, and lateral talocalcaneal angles ( $p > .05$ ) [206]. The another conducted study compared the footprint and radiographic measurements on 338 people and it was reported that there was a strong correlation between Staheli index, ChippauxSmirak index, and Grivas Classification System ( $p < .05$ ). On the other hand, the authors also emphasised a weak correlation between the radiological measurement methods calcaneal pitch and talo-first metatarsal angle and all three foot-print methods. In the current study, we developed the ArdAyak app and it has been tested on 28 feet, and the overall analysis has showed that the ArdAyak smartphone app has the moderate relationship of correlation between the sidas- custom station premium with  $r$  values of 0.468 (Table 4.22, Figure 4.4,  $p = .01$ ).

The literature emphasizes that the early detection of the risk factors of individuals with HP to increase the effectiveness of the combined physiotherapy methods to prevent chronicity and increased healthcare costs in the long term is crucial [10, 11, 68, 108]. However, there is still a gap in that so. Nowadays, tele-rehabilitation Technologies, such as smartphone application, web based Technologies, provides opportunities for evaluating and treating patients in clinical setting and during the patients' follow-up progress [218]. To date, many researchers have studied tele-rehabilitation as a home-based program and given that treatment is carried out via regular therapeutic exercises, that are needed to be performed correctly. According to these recent systematic reviews, most systems were primarily created for treatment and education. However, system innovation appears to be different in various domains of health [18, 114, 122].

To the best of our knowledge, there are no studies published to investigate the effectiveness of combined treatment strategies, including stretching and strengthening exercises, myofascial releasing, mulligan concept manual therapy regarding functional capacity, pain

and kinesiophobia. Additionally, there are no randomised controlled studies designed for HP tele-rehabilitation program as the home-based approach because more complete systems have been introduced in neurological and respiratory rehabilitation fields than in other areas [126, 141, 207].

There are a lot of validity and reliability of smartphone app against UG for various joint motions (the spinal column, knee, and ankle) studies and foot deformity detection tools [17, 122, 123, 128] . However, almost all of the smartphone apps that measure ROM require the integration of the phone to the body and a few of them measure ROM in weight bearing position. Additionally, devices that can detect the foot deformity are large, expensive without easily accessible and cannot be done through a smartphone-based app [13, 132, 163, 164]. For all these reasons, we investigated combined treatment strategies for HP patients. We developed e-health websites called Digital Steps ([www.dijitaladimlar.org/](http://www.dijitaladimlar.org/) [www.dijitaladimlar.yeditepe.edu.tr](http://www.dijitaladimlar.yeditepe.edu.tr)) for tele-rehabilitation. Additionally, we designed smartphone apps (DijiA & Ardayak) for evaluating ankle ROM and foot deformity remotely and analyzed their reliability.

There are a few limitations of the study. The first one was the absence of one-year follow-up assessment period and any outcomes from the long-term effects of the combined treatment strategies. Secondly, one of the smartphone apps we developed, DijiA, was for android, and Ardayak was for iOS phones. These apps should be developed in all phone software, and their effectiveness should be questioned. Moreover, according to the usability survey results, we think that the interface design of the DijiA application should be changed, and the correlation relationship should be increased by continuing the optimization tests of Ardayak and DijiA applications. Although we can check and control the usage of the [dijitaladimlar.org/](http://dijitaladimlar.org/) [dijitaladimlar.yeditepe.edu.tr](http://dijitaladimlar.yeditepe.edu.tr) website, which was developed as a tele-rehabilitation system, it is necessary to provide feedback to the patient by placing the tracking systems in it.

## 6. CONCLUSION

Hindfoot pain is frequently encountered in clinical practice. Extensive jogging, extended standing or walking, work-related weight-bearing activities, occupational environment, restricted ankle DF, a cavus foot, severe foot pronation, and psychological symptoms are considered to be related variables (e.g., stress, anxiety, and depression). For HP diseases, many treatment options have been offered, but the results have not been adequate, with no acknowledged combination therapy of choice and no clear prognostic markers. Thereby, We studied most common hindfoot pathologies-PFs & ATpathy-presented conservative treatments, focusing on functional capacity, pain, kinesiophobia and designed the smartphone-based app to assess ankle range of motion and foot deformities for patients with HP. Additionally, it was emphasizes that early detection and evaluation of the risk factors of HP can effectively lead to control and prevent these symptoms and their chronicity. That's why, we developed smartphone applications (DijiA & ArdAyak) and investigated the their effectiveness and reliability for evaluating ankle range of motion and foot deformity.

We would like to point out that;

- The combination of physiotherapeutic approaches, web-based tele-rabilitation and home-based rehabilitation are effective and convenient method for hindfoot pain management.
- Foot and ankle stretching and strengthening exercises protocols, myofascial releasing and mulligan concept manual therapy are efficient modalities in terms of ROM, VISA-A, FAAM, FFI, TSK and VAS scores for hindfoot pain.
- Foot and ankle stretching and strengthening exercises, myofascial releasing, mulligan concept manual therapy protocol can be more effective than only stretching and strengthening exercises protocol (web-based telerabilitation and home-based rehabilitation) as regard to improvement of function.
- Smartphone-based ankle ROM measurement with “DijiA” app can be used to assess active ROM of the ankle joint without weight-bearing. The result of the study showed that usability of DijiA app is satisfactory and above the standards.
- The smartphone app “Ardayak” may have the potential to be a convenient, easy-to-use, and feasible tool for the assessment of foot deformity with hindfoot pain patients.

➤ ‘Dijital Adımlar’, a web-based, smartphone-enabled tele-rehabilitation for management of hindfoot pain is a effective way and might be preferred instead of home-based tele-rehabilitation specially for kinesiophobia.

Overall, This research is the first randomized controlled trial to investigate the implementation of the effectiveness of tele-rehabilitation (web-based with smartphone-enabled) for HP exercises programme compared to conventional physiotherapy and traditional home-based rehabilitation with an evaluation of the risk factors of HP by smartphone apps. we summarized the effectiveness of conventional physiotherapy, focusing on The foot and ankle stretching and strengthening exercises protocols, myofascial releasing and mulligan concept manual therapy. For the hindfoot pain rehabilitation process, home-based physiotherapy is one of the essential items. According to the literature, tele-rehabilitation software solutions aimed at remote supervision of exercise programs have more or less standardized functions, offering comprehensive systems. However, research in this area is still in its early stages. A greater knowledge of these systems might help to improve their optimal design, resulting in better home-based programs and easier remote monitoring. Similarly, the smartphone ankle ROM measurement and foot deformity detection apps give the patient the advantage of monitoring their potential risk factors without buying the expensive devices. This motivates the patients for an enthusiastic self-rehabilitation and provides the determination of risk factors for hindfoot pain patients. Patients, physiotherapists, and physicians may use these apps to remotely measure a ROM in-home or clinic using a personal smartphone. Results of this study could lead to changes in practice guidelines on the treatment of hindfoot pain and the use of smartphone apps for injury prevention.

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## APPENDIX A: ETHICAL COMMITTEE APPROVAL



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

PROJENİN ADI : "Akıllı Telefon Temelli Uygulama ile Ard Ayaklarının  
Değerlendirilmesi ve Rehabilitasyonu"  
PROJENİN YÜRÜTÜCÜSÜ : Prof. Dr. Uğur ŞAYLI  
PROJEDEKİ ARAŞTIRICILAR : Dr.Tacha ŞERİF, Prof. Dr. Feryal SUBAŞI, Uzm. Fzt. Elif  
Tuğçe ÇİL, Gülşah GÖKHAN GÖKÇE  
ONAY TARİHİ VE SAYISI : 14.11.2019/129

**Sayın: Prof. Dr. Uğur ŞAYLI**

"129" protokol numaralı "Akıllı Telefon Temelli Uygulama ile Ard Ayaklarının Değerlendirilmesi ve Rehabilitasyonu" isimli projeniz Fakültemiz Etik Kurulu tarafından incelenmiş oy birliği ile etik yönden uygun olduğuna karar verilmiştir.

Prof. Dr. M. Gülden POLAT  
Etik Kurul Başkanı

## APPENDIX B: INFORMED WRITTEN CONSENT

### BİLGİLENDİRİLMİŞ ONAM FORMU

**Araştırmanın Adı:** Smart Phone-Based Application for Evaluation and Rehabilitation of HindFoot Pain

Sayın Katılımcı,

Yukarıda adı yazılı araştırmaya katılmak üzere davet edilmiş bulunmaktasınız. Bu araştırmada yer almayı kabul etmeden önce, araştırmanın ne amaçla yapılmak istendiğini anlamanız ve bu bilgilendirme sonucunda kararınızı vermeniz gerekmektedir. Aşağıdaki bilgileri lütfen dikkatlice okuyunuz, sorularınız olursa sorunuz ve açık yanıtlar isteyiniz. Bu araştırma ile sık rastlanan ard ayak ağrılarının akıllı telefon temelli uygulama ile değerlendirilmesi, rehabilitasyonu ve konvansiyonel fizyoterapi sonuçları ile kıyaslanması amaçlanmıştır. Bu araştırma, hastalara rahat ulaşım, ekonomik yükten koruma ve pratik uygulama kolaylığında yarar sağlayacaktır. Araştırma için Etik Kurul ve Yeditepe Üniversitesinden izin alınmıştır. Araştırmaya sizin dışınızda 119 kişi katılacaktır. Sizden bu çalışmada beklenen samimi, gerçekçi işbirliği ve öneriler rehabilitasyon programını yapmanız istenecektir. Bu işlem uygulamanın cevaplanması ve rehabilitasyon programı 30dk/seans alacaktır. Bunun size ve yakınlarınıza hiçbir zararı olmayacaktır. Çalışmaya katılmakla parasal yük altına girmeyeceksiniz ve size de herhangi bir ödeme yapılmayacaktır. Bu araştırmaya katılıp katılmamakta tümüyle özgürsünüz. Gerek duyduğunuz tüm bilgileri istemeye ve doğru, açık, anlaşılır bilgi almaya hakkınız vardır. Araştırmaya katılmayı istemezseniz burada size verilen hizmet olumlu veya olumsuz şekilde etkilenmeyecektir. Gerekli gördüğü takdirde araştırmanın herhangi bir kısmında katılımcı araştırmadan çıkabilir, araştırmacı çalışmayı sonlandırabilir. Araştırmanın tüm aşamalarında kimlik bilgileriniz gizli tutulacaktır. Araştırma kapsamında elde edilen bilgiler bilimsel amaçlarla kullanılabilir gizlilik kurallarına uyulmak kaydıyla sunulabilir ve yayınlanabilir. Araştırma ile ilgili daha fazla bilgiye ihtiyaç duyarsanız araştırmacıya elif.cil@yeditepe.edu.tr e-posta adresi veya 0554 481 10 92 numaralı telefondan ulaşabilirsiniz. Yukarıda yer alan ve araştırmaya başlanmadan önce katılımcılara verilmesi gereken bilgileri içeren metni okudum (ya da sözlü olarak dinledim). Araştırma kapsamında elde edilen şahsıma ait bilgilerin bilimsel amaçlarla kullanılmasını, gizlilik kurallarına uyulmak kaydıyla sunulmasını ve yayınlanmasını, hiçbir baskı ve zorlama altında kalmaksızın, kendi özgür irademle kabul ettiğimi beyan ederim

|                                |                                          |
|--------------------------------|------------------------------------------|
| <b>İmza/Tarih</b>              | <b>İmza/Tarih</b>                        |
| <b>Katılımcının adı soyadı</b> | <b>Sorumlu Araştırmacının adı soyadı</b> |



## APPENDIX C: Orthopedic Surgeon Clinical Examination And Physiotherapist Evaluation Form

### DEĞERLENDİRME FORMU

Hasta No:

|                                                             |       |                                                                 |
|-------------------------------------------------------------|-------|-----------------------------------------------------------------|
| Adı-Soyadı:                                                 | Yaşı: | Kadın <input type="checkbox"/> / Erkek <input type="checkbox"/> |
| Sağ <input type="checkbox"/> / Sol <input type="checkbox"/> | Boy:  | Kilosu:                                                         |
| Şikayet:                                                    | VKİ:  |                                                                 |
| Öykü:                                                       |       |                                                                 |
| Enflamatuvar patoloji, cerrahi vb.:                         |       |                                                                 |
| X-Ray:                                                      |       |                                                                 |
| Tanı:                                                       |       |                                                                 |

| VAS                      | TÖ | 8.hft | 6.ay |
|--------------------------|----|-------|------|
|                          |    |       |      |
| Sabah ilk yere basma ile |    |       |      |
|                          |    |       |      |
| Aktivite ağrısı          |    |       |      |
|                          |    |       |      |
| Gece ağrısı              |    |       |      |
|                          |    |       |      |

### Gonyometrik Ölçüm

Ayak bileği plantar fleksiyon: Sağ: Sol:

Ayak bileği dorsifleksiyon: Sağ: Sol:

|                          |    |       |
|--------------------------|----|-------|
| Tampa Kinezyofobi Skoru: | TÖ | 8.hft |
|                          |    |       |
| VISA-A Skoru             | TÖ | 8.hft |
|                          |    |       |
| FFI Skoru                | TÖ | 8.hft |
|                          |    |       |

## APPENDIX D: MOBILE APPLICATION FORM AND USABILITY TEST

**Ardayak Ağrısı**

**Ad - Soyad**

**Telefon numarası / E-mail**

**1-Doğum Tarihi**

2-( ) Kadın ( ) Erkek

3-Boy uzunluğu (cm).....

4-Vücut ağırlığı (kg).....

5-Dominant (En çok kullandığınız )Taraf

( ) Sağ ( ) Sol

6)Kronik ( süreğen) bir hastalığınız var mı? var ise lütfen aşağıda belirtiniz

*( Birden Fazla Seçenek işaretleyebilirsiniz)*

( ) Kronik bir hastalığım yok

( ) Bel Ağrısı ( Fıtık dahil )

( ) Dahili Hastalıklar (Tiroid, Hipertansiyon, Kalp rahatsızlıkları vb.)

( ) Nörolojik (Parkinson, Multiple skleroz, felç

( ) Diğer

7) Son 3 ayda herhangi bir yaralanma/travma/ ameliyat geçirdiniz mi ?

*( Birden Fazla Seçenek işaretleyebilirsiniz)*

( ) Evet ( ) Hayır

Evet ise lütfen belirtiniz

( ) Ayak- Ayak bileği ( ) Diz ( ) Kalça ( ) Diğer.....

**SAĞ ve SOL ayak için ayrı ayrı gelecek sorular**

**8) Sabah ilk adımınızda topuk ve ayak tabanınızdaki ağrının derecesini lütfen değerlendirin.**

(Ağrı yok) 0 1 2 3 4 5 6 7 8 9 10 (Dayanılmaz ağrı)

**9) Bu ağrınız fiziksel aktiviteyle artıyor mu ? Ağrının derecesini lütfen değerlendirin.**

(Ağrı yok ) 0 1 2 3 4 5 6 7 8 9 10 (Dayanılmaz ağrı)

**10) Bu ağrınız gece var mı ?**

( ) var ( ) yok



İlgili Uzmanla Başvurunuz  İletişim Bilgileri

**11) Ne kadar zamandır bu probleminiz var ?**

**12) Ağrınızın yerini işaretleyiniz**

Fotoğraf gelecek

**13) Ayağınız Hangisine Daha çok benziyor ?**

Fotoğraf gelecek

**14) Ayak röntgen görüntünüz (basarken) varsa ise lütfen gönderiniz**

**15) Ayak bileği hareket sınırınızın limitlerini gösterebilir misiniz ? ( Video simülasyonu)**



|    |                                                                                                       |                          |                          |                          |                          |                          |
|----|-------------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 9  | Uygulama yararlı yardım bilgileri sağlar.                                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10 | Uygulama, bir görevin / faaliyetin nasıl gerçekleştirileceğini açıklayan faydalı görsel öğeler sunar. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11 | Uygulamada kullanılan dili anlamak zordu.                                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12 | Konular / kavram ve bilgi anlaşılırdı.                                                                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13 | Görevleri tamamlayabilmek için ekranlar arasında aklımda tutmam gereken bilgiler çok fazla.           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14 | Çok fazla çaba sarf etmeden görevleri tamamlayabildim.                                                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15 | Uygulamayı kullanmayı öğrenmek zordu.                                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16 | Uygulama her faaliyet sonunda ilerleme raporu / sonucu sunuyor.                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17 | Uygulama açıkça bana sorunları nasıl çözeceğini söyleyen hata mesajları veriyor.                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 18 | Bu uygulamadaki metni okumak kolaydı.                                                                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 19 | Uygulamada kullanılan metin boyutu çok küçüktü.                                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 20 | Bu uygulamada kullanılan animasyon ve görüntüleri sevdim.                                             | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

|    |                                                                                                |                          |                          |                          |                          |                          |
|----|------------------------------------------------------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 21 | Uygulamada kullanılan müzik ve sesler rahatsız edici idi.                                      | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 22 | Uygulama tasarımını güzel buluyorum.                                                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 23 | Bu uygulamada kullanılan renkler güzel değil.                                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 24 | Kullanılan simgeler ve düğmeler güzel ve tanınabilir.                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 25 | Genel olarak uygulamayı kullanmaktan zevk aldım.                                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 26 | Bu uygulamayı sıklıkla kullanmak isteyeceğimi düşünüyorum.                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 27 | Uygulamayı fazla karmaşık buldum.                                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 28 | Uygulamanın kullanımının kolay olduğunu düşündüm.                                              | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 30 | Bu uygulamayı kullanabilmek için teknik bir kişinin desteğine ihtiyacım olacağını düşünüyorum. | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 31 | Bu uygulamadaki çeşitli fonksiyonların uygulamaya iyi yerleştirildiğini gördüm.                | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 32 | Uygulamada çok fazla tutarsızlık olduğunu düşündüm.                                            | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 33 | Çoğu insanın bu uygulamayı çok hızlı bir şekilde kullanmayı öğreneceğini düşünüyorum.          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 34 | Uygulamayı çok hantal (yavaş) buldum.                                                          | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 35 | Uygulamayı kendimden emin şekilde kullanabildim.                                               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 36 | Bu uygulamayı kullanmadan önce birçok şey öğrenmem gerekiyor.                                  | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

## APPENDIX E: VISUAL ANOLOGUE SCALE (VAS)

### VİZUEL ANALOG SKALA (VAS)

Adınız Soyadınız: \_\_\_\_\_ Tarih: \_\_\_\_\_

Ağrı şiddetinizi aşağıdaki ölçek üzerinde işaretleyin.

Hiç ağrı olmaması

En dayanılmaz ağrı





7. Tabanlıkla yürürken 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 | SAG | SOL |
|----------|---|---|---|---|---|---|---|---|---|---|----|-----------------------------|-----|-----|

8. Tabanlıkla ayakta dururken 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 | SAG | 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 | SAG | SOL |
|----------|---|---|---|---|---|---|---|---|---|---|----|-----------------------------|-----|-----|

## YETERSİZLİK: NE KADAR ZORLUK ÇEKİYORSUNUZ?

1. Evin içinde yürürken ne kadar zorluk çekiyorsunuz?

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAG | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|

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

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAĞ | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|

3. 300 metre yol yürüdüğünüzde ne kadar zorluk çekiyorsunuz?

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAĞ | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|

4. Merdiven çıkarken ne kadar zorluk çekiyorsunuz?

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAĞ | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|

5. Merdiven inerken ne kadar zorluk çekiyorsunuz?

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAĞ | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|

6. Ayak parmaklarınızın ucunda dururken ne kadar zorluk çekiyorsunuz?

|            |                               |                               |                               |                               |                               |                               |                               |                               |                               |                               |                                |                         |     |     |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|
| Zorluk yok | 0<br><input type="checkbox"/> | 1<br><input type="checkbox"/> | 2<br><input type="checkbox"/> | 3<br><input type="checkbox"/> | 4<br><input type="checkbox"/> | 5<br><input type="checkbox"/> | 6<br><input type="checkbox"/> | 7<br><input type="checkbox"/> | 8<br><input type="checkbox"/> | 9<br><input type="checkbox"/> | 10<br><input type="checkbox"/> | Yapılamayacak kadar zor | SAG | SOL |
|------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|-------------------------------|--------------------------------|-------------------------|-----|-----|



## APPENDIX G: THE VICTORIAN INSTITUTE OF SPORTS ASSESSMENT – ACHILLES QUESTIONNAIRE (VISA-A)

### VISA-A-TR SKORLAMA FORMU

(Viktoria spor deęerlendirme enstitüsü - Aşıl Tendinopati - Türkçe skorlama formu)

İsim: \_\_\_\_\_ Tarih: \_\_\_\_\_ Etkilenen ekstremité: Sağ / Sol  
Yaş: \_\_\_\_\_  
Protokol no: \_\_\_\_\_

1. Uyandıęınızda Aşıl tendon bölgesinde kaç dakikalık bir sertlik hissediyorsunuz?

100 dak 

|            |           |           |           |           |           |           |           |           |           |          |
|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| 100<br>dak | 90<br>dak | 80<br>dak | 70<br>dak | 60<br>dak | 50<br>dak | 40<br>dak | 30<br>dak | 20<br>dak | 10<br>dak | 0<br>dak |
| 0          | 1         | 2         | 3         | 4         | 5         | 6         | 7         | 8         | 9         | 10       |

 0 dak

Puan

2. Isındıktan sonra, diz gergin vaziyetteyken ayak parmaklarınızı kendinize çekip Aşıl tendonunuzu gerginleştirdiğinizde ağrı hissediyor musunuz?

Şiddetli ağrı 

|   |   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|---|----|
|   |   |   |   |   |   |   |   |   |   |    |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

 Ağrı yok

Puan

3. Düz bir zeminde 30 dakika yürüdükten sonraki iki saat boyunca ağrı hissediyor musunuz?  
(ağrı yüzünden 30 dakika boyunca düz bir zeminde yürüyemiyorsanız bu soru için skor sıfırdır)

Şiddetli ağrı 

|   |   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|---|----|
|   |   |   |   |   |   |   |   |   |   |    |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

 Ağrı yok

Puan

4. Normal yürüyüş düzeni içerisinde, merdivenden aşağı inerken ağrınız oluyor mu?

Şiddetli ağrı 

|   |   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|---|----|
|   |   |   |   |   |   |   |   |   |   |    |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

 Ağrı yok

Puan

5. Düz bir zeminde, 10 kez parmaklar ucuna kalkma sırasında veya yaptıktan hemen sonra ağrınız oluyor mu?

Şiddetli ağrı 

|   |   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|---|----|
|   |   |   |   |   |   |   |   |   |   |    |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

 Ağrı yok

Puan

6. Ağrısız olarak kaç defa tek ayak üzerine zıplayabiliyorsunuz?

0 

|   |   |   |   |   |   |   |   |   |   |    |
|---|---|---|---|---|---|---|---|---|---|----|
|   |   |   |   |   |   |   |   |   |   |    |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

 10

Puan

7. Her hangi bir fiziksel aktivite veya spor yapıyor musunuz?

- 0 ☐ Hiç yapmıyorum.
- 4 ☐ Kendime uygun egzersiz ve/veya rekabetli sporları yapıyorum.
- 7 ☐ Tam egzersiz ve rekabet gerektiren sporları yapabiliyorum, ancak şikâyetler başladıktan sonra daha az yapabiliyorum.
- 10 ☐ Şikâyetlerin başladığı seviyede veya daha yüksek seviyede rekabet ve yarışabiliyorum.

Puan

8. Lütfen bu soruda A, B veya C şıklarından **sadece birini** doldurunuz.

— Eğer Aşil tendon üzerine yükleme sporları yaptığınızda ağrı olmuyorsa sadece soru 8A'yı doldurunuz.

— Eğer Aşil tendon yükleme sporu yaptığınızda ağrı oluyorsa fakat aktivitenizi tamamlamayı etkilemiyorsa sadece 8B şıkını doldurunuz.

— Eğer Aşil tendon yükleme sporu yaptığınızda ağrı aktivitelerinizi durduruyorsa 8C şıkını doldurunuz.

A. Aşil tendon yükleme sporu yaptığınızda ağrınız olmuyorsa, egzersiz ve/veya antrenmanı ne kadar süreyle yapabiliyorsunuz?

| 0 dak                | 1-10 dak             | 11-20 dak            | 21-30 dak            | >30 dak              |
|----------------------|----------------------|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 0                    | 7                    | 14                   | 21                   | 30                   |

Puan

B. Aşil tendon yükleme sporu yaptığınızda biraz ağrınız oluyorsa, fakat bu durum sizin antrenman veya egzersizinizi tamamlamanıza engel olmuyorsa, ne kadar süre ile antrenman veya egzersiz yapabiliyorsunuz?

| 0 dak                | 1-10 dak             | 11-20 dak            | 21-30 dak            | >30 dak              |
|----------------------|----------------------|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 0                    | 4                    | 10                   | 14                   | 20                   |

Puan

C. Aşil tendon yükleme sporu yaptığınızda duyduğunuz ağrı sizin antrenmanınızı durdurmaya neden oluyorsa, ne kadar süre ile antrenman veya egzersiz yapabiliyorsunuz?

| 0 dak                | 1-10 dak             | 11-20 dak            | 21-30 dak            | >30 dak              |
|----------------------|----------------------|----------------------|----------------------|----------------------|
| <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> | <input type="text"/> |
| 0                    | 2                    | 5                    | 7                    | 10                   |

Puan

Toplam skor ( /100 )

%

Not: Şikâyetlerin süresi (Δv) =

## APPENDIX H: TAMPA SCALE FOR KINESIOPHOBIA (TSK)

| Lütfen, her soruda kendinize en uygun olan kutucuğu işaretleyiniz (her soruda yalnızca bir kutucuğu işaretleyiniz). Teşekkür ederiz. |                            |                          |                          |                          |
|--------------------------------------------------------------------------------------------------------------------------------------|----------------------------|--------------------------|--------------------------|--------------------------|
|                                                                                                                                      | Kesinlikle<br>katılmıyorum | Katılmıyorum             | Katılıyorum              | Tamamen<br>katılıyorum   |
| 1. Egzersiz yaparsam kendi kendimi sakatlarım diye kaygılanıyorum.                                                                   | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. Ağrıyla baş etmeye çalışacak olsam, ağrım artar.                                                                                  | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. Ağrımdan dolayı vücudum bana tehlikeli derecede yanlış giden bir şeyler olduğunu söylüyor.                                        | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. Egzersiz yaparsam sanki ağrım hafifleyecekmiş gibi geliyor.                                                                       | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. İnsanlar benim tıbbi sorunlarımı yeterince ciddiye almıyorlar.                                                                    | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Başıma gelen bu olay nedeni ile vücudum hayat boyu risk altında olacak.                                                           | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 7. Ağrının olması her zaman, vücudumu sakatladığım/bir problemim olduğu anlamına gelir.                                              | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. Sırf bazı şeylerin ağrımı artırıyor olması, onların tehlikeli oldukları anlamına gelmez.                                          | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 9. Kendimi kazara sakatlamaktan korkuyorum.                                                                                          | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. Ağrının artmasını engellemenin en basit ve güvenli yolu gereksiz hareketler yapmaktan kaçınmaktır.                               | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. Vücudumda tehlike arz eden bir şey olmasaydı, bu kadar çok ağrı hissetmezdim.                                                    | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. Ağrıma rağmen, fiziksel olarak aktif olsaydım, durumum daha iyi olurdu.                                                          | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 13. Ağrı, kendimi sakatlamamam için egzersizi ne zaman bırakmam gerektiği konusunda bana sinyal verir.                               | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. Benim durumumda olan birinin, fiziksel olarak aktif olması pek güvenli değildir.                                                 | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15. Normal insanların yaptığı her şeyi yapamam, çünkü çok kolay sakatlanırım.                                                        | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16. Bazı şeyler çok fazla ağrıya neden olsa bile, bunların gerçekte tehlikeli olduklarını düşünmem.                                  | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17. Hiç kimse ağrı hissederken egzersiz yapmak zorunda olmamalı.                                                                     | <input type="checkbox"/>   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

## APPENDIX İ: THE FOOT AND ANKLE ABILITY MEASURE (FAAM)

### AYAK VE AYAK BİLEĞİ KULLANILABİLİRLİK ÖLÇÜSÜ

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

|                                   | Hiç zor değil            | Hafif zor                | Orta derece zor          | Aşırı zor                | Yapamıyorum              | Uygulanamaz              |
|-----------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Ayakta durmak                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Düz zeminde yürümek               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Düz zeminde ayakkabısız yürümek   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Yokuş yukarı çıkmak               | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Yokuş aşağı inmek                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Merdiven çıkmak                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Merdiven inmek                    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Düz olmayan zeminde yürümek       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Kaldırımdan inip- kaldırma çıkmak | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Çömelme                           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Ayak parmakları üzerinde durmak   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Yürümeye başlamak                 | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5 dakika ya da daha az yürümek    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10 dakika kadar yürümek           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 15 dakika ve ya daha uzun yürümek | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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

|                                                   | Hiç zor değil            | Hafif zor                | Orta derece zor          | Aşırı zor                | Yapamıyorum              | Uygulanamaz              |
|---------------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Ev işleri                                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Günlük yaşam aktiviteleri                         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Kişisel bakım                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Hafif-orta düzeyde işler (ayakta durmak, yürümek) | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Ağır işler (itme/çekme, turmanma, taşıma)         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Rekreatif (eğlence ve sosyal) aktiviteler         | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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

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

|                                              | Hiç zor değil            | Hafif zor                | Orta derece zor          | Aşırı zor                | Yapamıyorum              | Uygulanamaz              |
|----------------------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| Koşmak                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Zıplamak                                     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Atlama                                       | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Harekete aniden başlayıp durabilme           | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Makaslama ve yana doğrultulu hareketleri     | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Düşük seviyeli aktiviteler                   | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Normal tekniklerle aktiviteleri yapabilme    | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| Sevdiğiniz sporu istediğiniz kadar yapabilme | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

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

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Genel olarak şu anki fonksiyonunuzu nasıl değerlendirirsiniz?

☐ Normal ☐ Normale Yakın ☐ Anormal ☐ Ciddi Anormal