A SURFACE ELECTROMYOGRAPHY BASED SERIOUS COMPUTER GAME FOR PHYSIOTHERAPY AND REHABILITATION

(FIZYOTERAPI VE REHABILITASYON İÇIN YÜZEYEL ELEKTROMIYOGRAFI BAZLI CIDDI BILGISAYAR OYUNU)

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This is to certify that the thesis entitled

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ABSTRACT

This master thesis study offers a serious game concept, for lower extremity muscles strengthening exercises for physiotherapy and rehabilitation and a feedback module to physiotherapists for following-up their patients remotely. The proposed system is a complete game and feedback system, where the exercises are transformed into game activities and monitored by collecting surface electromyography signals using BITalino that is a wearable data acquisition board. The feedback to the physiotherapist contains data related to the performance of the patients. UNITY Game Engine is used as the game design platform. This game system provides a goal-oriented exercise training to the patients for increasing their motivations and thus, improving the patient participation to the treatment. A web application is developed as a feedback module that contains a set of analysis results and information about the patient's progress.

The recommended exercises for the patient with lower limb injuries should be performed regularly for a successful physical therapy. These include active knee extension for quadriceps muscle (i.e, Quadriceps Exercise), active knee flexion for hamstring muscles (i.e, Hamstring Exercise) and terminal extension exercise for vastus medialis obliquus muscle (i.e, Terminal Isometric Exercise). The fidelity to the therapy schedule and the improvement of the patient can be evaluated by collection and analysis of amplitude and frequency of the surface electromyographic (sEMG) signals that vary according to the contraction force of the muscles. The patient stretches according to the goals of the different ball games and real-time sEMG signals are simultaneously recorded using BITalino. Only a single surface electromyography channel is used for this study. The raw electromyography signal is noisy due to its nature and therefore is adequately processed. The game environment motivates the patient in performing the otherwise tedious exercise routines.

Another advantage of the proposed system is to provide to the physiotherapist, information about the progress of the patient during physiotherapy and rehabilitation treatment. The physiotherapist could follow his/her patient remotely and monitor his/her progress during exercise sessions.

The requirements for this system are determined by discussing with physiotherapists. EMG signals are collected from volunteer subjects. İstinye University Clinical Research Ethics Committee approved the study.

In summary, physiotherapy and rehabilitation treatments which are boring and very long for the patients turn into a computer game and a feedback module with the analysis of patient progress enabled the physiotherapists to follow their patients remotely.

Keywords : electromyography; sEMG; signal processing; serious game; physiotherapy and rehabilitation; gamification

RÉSUMÉ

Cette étude de thèse propose un système de jeu sérieux pour les exercices de renforcement des muscles des membres inférieurs en physiothérapie et en réadaptation, ainsi qu'un module de feedback aux physiothérapeutes pour le suivi à distance de leurs patients. Le système proposé est un système complet de jeu et de rétroaction, dans lequel les exercices sont transformés en activités de jeu et contrôlés en collectant des signaux d'électromyographie de surface à l'aide de BITalino, une carte d'acquisition de données portable, et la rétroaction au physiothérapeute contient des données relatives aux performances des patients. . UNITY Game Engine est utilisé pour la plate-forme de conception de jeux. Ce système de jeu offre aux patients un entraînement axé sur des objectifs visant à accroître leurs motivations et, partant, à accroître la participation des patients au traitement. Une application Web conçue pour le module de commentaires contient un ensemble d'analyses et d'informations sur le patient.

Les exercices recommandés pour le patient souffrant de lésions des membres inférieurs doivent être effectués régulièrement pour une thérapie physique réussie. Ceux-ci comprennent l'extension active du genou pour le muscle quadriceps (c'est-à-dire l'exercice de quadriceps), la flexion active du genou pour les muscles ischio-jambiers (c'est-à-dire l'exercice du jarret) et l'exercice d'extension terminale du muscle vastus medialis obliquus (c'est-à-dire l'exercice isométrique terminal). La fidélité au programme de traitement et l'amélioration du patient peuvent être évaluées par la collecte et l'analyse de l'amplitude et de la fréquence des signaux électromyographiques de surface (SEMG) qui varient en fonction de la force de contraction des muscles. Le patient se déplace en fonction des objectifs des différents jeux de ballon. Les signaux sEMG en temps réel sont simultanément enregistrés avec BITalino. Un seul canal d'électromyographie de surface est utilisé pour cette étude. Le signal d'électromyographie brut est bruyant en raison de sa nature et est rendu précieux et plus significatif par un traitement approprié. L'environnement de jeu motive le patient à effectuer les exercices fastidieux.

Un autre avantage du système proposé est qu'il offre au physiothérapeute des informations sur les progrès du patient au cours du traitement de physiothérapie et de

rééducation. Le physiothérapeute peut suivre son patient à distance et surveiller ses progrès. L'analyse des séances d'exercices du patient (via l'analyse des signaux EMG acquis) est présentée au physiothérapeute.

Les exigences de ce système sont déterminées en discutant avec des physiothérapeutes. Les signaux EMG sont collectés auprès de sujets volontaires pour comprendre et analyser les signaux EMG. Le comité d'éthique de la recherche clinique de l'université d'Istinye a approuvé cette étude. Les bénéfices cliniques du système doivent être évalués à l'aide de méthodes d'analyse statistique médicale.

Par conséquent, les traitements de physiothérapie et de rééducation qui sont ennuyeux et très longs pour les patients se transforment en un jeu d'ordinateur. Un module de rétroaction avec analyse des progrès du patient est conçu et une possibilité de suivre les patients à distance est fournie aux physiothérapeutes.

Mots Clés : électromyographie; sEMG; traitement de signal; jeu sérieux; physiothérapie et réhabilitation; ludification

ÖZET

Bu yüksek lisans tez çalışması, fizyoterapi ve rehabilitasyonda hastalara tavsiye edilen alt ekstremite kasları güçlendirici egzersizler için ciddi bir oyun sistemi ve fizyoterapistler için hastalarını uzaktan izlemelerini sağlayan bir geri bildirim modülü sunmaktadır. Önerilen sistem, egzersizlerin oyun aktivitelerine dönüştürüldüğü, giyilebilir bir veri toplama aygıtı olan BITalino kullanılarak yüzey elektromiyografi sinyallerinin hastalardan egzersiz esnasında toplanarak analiz edildiği ve fizyoterapistlere hastalarının EMG analiz sonuçlarını izleme fırsatı sunan, tamamlanmış bir oyun ve geri bildirim sistemidir. UNITY oyun motoru oyunlar için kullanılmıştır. Bu oyun sistemi, hastaları motive ederek hastaların tedaviye katılımını arttırmak için amaca yönelik bir egzersiz eğitimi sunmaktadır. Geri bildirim modülü için, hasta ilerlemeleri hakkında bir dizi analiz ve bilgiyi görüntülemeye yarayan bir web uygulaması tasarlanmıştır.

Elektromiyografi, kasların kasılmasıyla üretilen elektriksel bir aktivitedir. Üretilen elektromiyografi, kasların kasılma kuvvetine göre değişir. Önerilen egzersizler, kuadrisepskası için aktif diz uzamasıdır (Quadriceps Egzersizi), hamstring kasları için aktif dizfleksiyonu (Hamstring Egzersizi) ve vastus medialis obliquus kası için terminal ekstan-siyon egzersizi (Terminal İzometrik Egzersizi). Gerçek zamanlı yüzey elektromiyografisinyalleri BITalino'dan UNITY oyun motoruna alınır ve daha sonra oyuncu (kullanıcı,oyun içinde top) işlenmiş elektromiyografi sinyallerine göre hareket eder ve böyleceoyuncu puan toplar. Oyunlarda, oyuncu bir toptur, yani hasta oyunlardan birini oyna-dığında; ekrandaki topu hareket ettirir. Bu çalışma için sadece tek bir yüzey elektromi-yografi kanalı kullanılmıştır. Ham elektromiyografi sinyali, doğası gereği gürültülüdürve bazı metotlar kullanılarak değerli ve anlamlı hale getirilir. Elde edilen veriler farklıuygulamalarda kullanılabilir. Bu çalışmada, işlenen sinyaller oyun nesnesini (top) ha-reket ettirmek için girdi olarak kullanılmaktadır.

Önerilen sistemin bir başka avantajı da, fizyoterapist ve fizik tedavi uzmanına fizyoterapist tedavisi sırasında hastanın ilerlemesi hakkında bilgi vermesidir. Fizyoterapist hastasını uzaktan takip edebilir ve gelişimini izleyebilir. Hastanın egzersiz seanslarının analizi (edinilen EMG sinyallerinin analizi ile) fizyoterapiste sunulur.

Bu sistemin gereksinimleri fizyoterapistlerle tartışılarak belirlenmiştir. EMG sinyallerini anlamak ve analiz etmek için gönüllülerden EMG sinyalleri toplanmıştır. İstinye Üniversitesi Klinik Araştırmalar Etik Kurulu tarafından bu çalışmayı onaylanmıştır. Sistemin klinik faydası tıbbi istatistik analiz yöntemleri kullanılarak değerlendirilmelidir.

Sonuç olarak, hastalar için sıkıcı ve uzun süren fizyoterapi ve rehabilitasyon tedavileri bir bilgisayar oyununa dönüştürülmüş ve hastanın ilerlemesini analizlerle gösteren bir geri bildirim modülü tasarlanmış ve fizyoterapistlere hastaları uzaktan izleme olanağı sunulmuştur.

Anahtar Kelimeler : elektromiyografi; sEMG; sinyal işleme; ciddi oyun; fizyotrapi ve rehabilitasyon; oyunlaştırma

LIST OF ABBREVIATIONS

sEMG	:	Surface Electromyography
EMG	:	Electromyography
RMS	:	Root Mean Square
MAV	:	Mean Absolute Value
MAD	:	Mean Absolute Deviation
WA	:	Wavelet Analysis
AR	:	Autoregressive Model
AI	:	Artificial Intelligence
ANN	:	Artificial Neural Network
HOS	:	Higher-Order Statistics
VAR	:	Variance of EMG

1 INTRODUCTION

Physiotherapy and rehabilitation treatment is a repetitive and tedious process. Therefore, many patients are faced with problems such as lack of motivation and reluctance to stay in treatment. However, for treatment to be successful, the regular attendance and the continuity of the patient is crucial. Increasing patient participation in treatment results in improvement in treatment success rates. Several studies have shown that creating a concept and goal-setting increases the patients' motivation (Melin, 2018).

Serious game is a concept that is being used in various fields such as education, rehabilitation, engineering and health care where the first aim is not entertaining the target population. It has been shown that enhancing traditional physiotherapy methods with the approach of serious gaming is beneficial in increasing the patients' engagement and motivation (Rego et al., 2010).

Electromyogram is a bioelectrical signal : an electrical activity, that is produced by muscles during contraction. Electromyography is a technique that measures and records the generated electrical activity. If the electrodes are applied on the skin instead of needles inserted into the subcutaneous tissue, it is called surface electromyography and therefore is a non-invasive technique (Merletti et al., 2001).

Signal processing is a field of computer science for extracting information from the signals and finding out attributes related to them. There are different signal processing techniques according to the nature and characteristics of the signal of interest (Rabiner and Gold, 1975).

In this master thesis study, a serious computer game concept for physiotherapy and rehabilitation of lower limb by using sEMG signals is presented accompanied with a feedback module for following-up the patients remotely. In Section II, a detailed literature review is given. Section III describes the system architecture, devices, tools and solutions that are used. Materials and methods are explained in Section IV and then in Section V results are shown. Finally, the master thesis study is concluded in Section VI.

2 LITERATURE REVIEW

In the literature, one can remark that serious game concept is widely used in recent years. The studies in this area include both technological developments and methodological progressions (Ritterfeld et al., 2009). Serious game concepts that employ different techniques and methods, for education, rehabilitation, health, can be seen both in academic and industrial research.This section begins with a general overview of the studies in the serious game field. It then focuses on serious games based on physiological signals especially surface electromyography (sEMG) for physiotherapy and rehabilitation.

According to a technical report published in 2007 (Susi et al., 2007), the serious game notion, has acquired a significant interest within the sector. The report explains serious game concept and markets with the help of related literature. Although being defined by many different terms and content, serious game concept aims at useful outputs such as efficient learning or treatment by using entertainment as a tool. The main players of the serious game industry, whose usage is in a wide range from health to military, are especially in North America and Europe according to this report.

An article published in 2012, presents an extensive literature review of serious games (Connolly et al., 2012). Its aim is to categorize computer games in the literature by examining 129 different studies : they are classified according to different aspects such as their subjects, outputs and quality levels. The distributions are shown in Table **2.1** according to the outcomes of 70 different studies (studies with quality rate higher than 9, by the criterion of article) for this review. This broad study offers an evidence-based review of serious games.

Table**2.1**: Number of Reviewed Studies by Type of Outcome

Number of Reviewed Studies	**Type of Outcome**
18	Affective and Motivational
8	Behavioural Change
17	Knowledge Acquisition/Content Understanding
4	Motor skills
13	Perceptual and Cognitive Skills
6	Physiological Arousal
4	Soft skills and Social

In an article which reviewed the development of serious games for health, the design criteria are discussed by considering the behavior of patients (Thompson et al., 2010). An example in this survey shows a serious game aimed at changing people's behavior

to prevent type 2 diabetes and obesity : Escape From Diab (Diab). The target audience is relatively young people (10-12 years old) with computer access.

Another article published in 2009 on rehabilitation-related serious game, which is also the starting point of this master's thesis, examines a few serious games that increase patient participation in post-stroke rehabilitation (Burke et al., 2009). It focuses on upper limb rehabilitation. Designed serious game setup uses video capture techniques and is low-cost and therefore easy to become widespread.

A review article published in 2010 also refers to serious game fundamentals, especially, serious game examples in rehabilitation and their criteria (Rego et al., 2010). The recommended serious games for rehabilitation are classified according to the specified criteria that are explained in Table **2.2**. Many serious games examined in this study have been evaluated according to these criteria and a study has been taken as an example : RehaCom. It is for cognitive rehabilitation and it adapts according to patient progress.

Table**2.2**: The Criteria and Explanations

The Criteria	**Explanation**
Field of Application.	Motor or Cognitive Rehabilitation
Using Tech.	Motion Tracking, Keyboard, Joystick etc.
Dimension of Game.	2D or 3D
Player Number.	Single or Multi Player
Game Style.	Memory, Simulation, Strategy or Assorted etc.
Adaptiveness.	Yes or No (is it dynamic according to patient performance ?)
Performance Feedback.	Yes or No (can patient see his/her progress ?)
Follow-up	Yes or No (do system save the results ?)
Place of the Game	Home, Clinic, Hospital etc.

Four mini-games are introduced in another study that proposes a handy architecture for a rehabilitation oriented serious game (Omelina et al., 2012). The system consists of 3 main layers : Game controls layer, game configuration layer and games **2.1**.

One of the most interesting aspects of this study is that it can receive data from many different input interfaces such as Kinect, 3D cameras, keyboard etc.

This master thesis study uses as input electromyography signals for the serious game control. sEMG analysis methods are used for the feedback module to the physiotherapist. The literature of sEMG analysis method is also mentioned in this chapter.

In an article published in 2006, a large study was conducted on EMG signal analysis

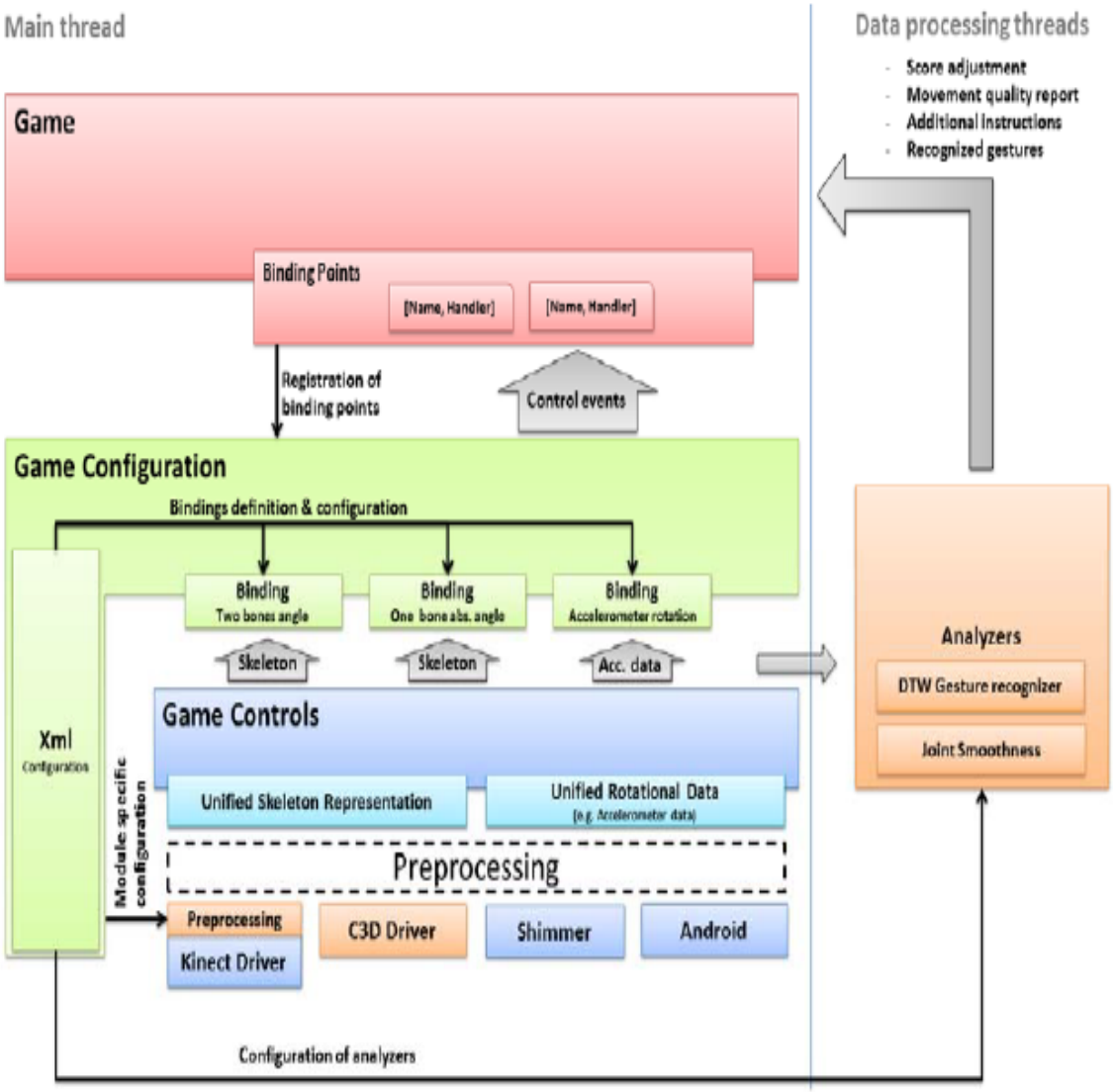

Figure **2.1**: System Architecture of (Omelina et al., 2012)

(Reaz et al., 2006). In the literature there are different signal processing methods that can be applied to raw EMG data, according to the usage of the signal. This study reviewed these methods for EMG signals : Wavelet analysis (WA) is a widely used and powerful signal processing method that is suitable for the non-stationary structure of the EMG data. Time-frequency analysis and other time or frequency domain approaches have also been applied in various studies in order to analyze the signal. Artificial Intelligence (AI) methods that are based on artificial neural networks (ANN) are proposed for real-time signal processing. Due to the nature of the EMG signal, statistical methods such as Higher-order statistics (HOS), are also suitable for signal processing.

A study published in 2005 provides an extensive review of EMG and addresses the whole process from acquisition to analysis of the signal in detail (Konrad, 2005). The article,

which deals with algorithms and filters used in EMG signal processing, also shows the applications of the mentioned methods. The study consists of three main parts : Signal Origin and Acquisition, Signal Processing and EMG Analysis. Signal Origin and Acquisition part presents nature of EMG signal, its acquisition, representation of EMG signal etc. Signal Processing part contains rectification of EMG : all negative amplitudes have to be converted to positive amplitudes for reading EMG signal easily, to apply the curve of EMG signal standard amplitude parameters.

Raw EMG signals contains impulsive noise components and digital signal smoothing algorithms are applied to reduce them in order to improve signal to noise ratio (SNR). Simple algorithms such as Moving average (Movag) and Root Mean Square (RMS) are used to get an estimate of the signal power filtered from the noise. Movag is the average of some definite data by using the sliding window technique. RMS represents the mean power of the signal. These two algorithms are recommended for smoothing.

Low-Pass and/or High-Pass filters can be used for cleaning artifacts from the EMG signal. One of the most important problems in EMG signal analysis is that the amplitude can vary in a large range. As a solution, the EMG signal can be normalized relative to a reference value, such as the maximum voluntary contraction (MVC) value of a reference contraction. The most important benefit of MVC is the ability to predict the effort needed for an exercise or task. Temporal normalization is used because it is impossible to reproduce exactly the movements of people. Thus, an average value is obtained for a motion (Figure **2.2**).

In frequency analysis of EMG signals Fast Fourier Transformation (FFT) can be used quite easily. FFT provides a decomposition of the EMG signal power into different frequency bands. As an alternative to FFT, Zero Crossing can be used to estimate the main frequency of the EMG signal. The article also explores the relationship between the amplitude of the EMG signal and the force produced by the muscle (Figure **2.3**).

In a study published in 2015, mean absolute value (MAV) is used for contractile force of muscle, root mean square (RMS) is used to represent the amplitude of the EMG. The variance (VAR) yields the power of the EMG (Jahan et al., 2015).

A brief literature review of EMG analysis and Serious Game given in this section shows that serious game approach is a very popular concept especially in the rehabilitation research (Pauk, 2008) (Chowdhury et al., 2013).

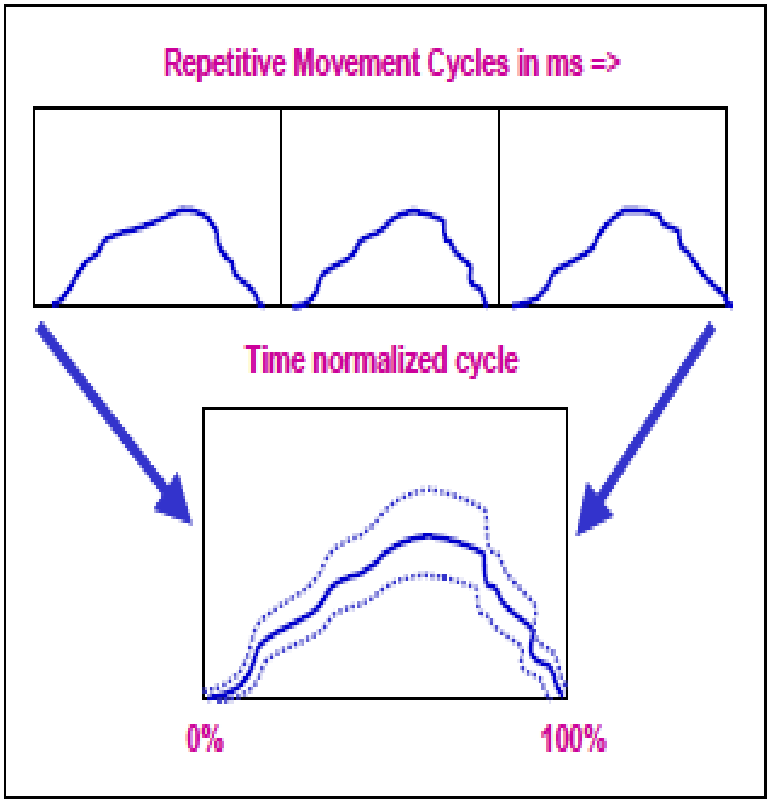

Figure **2.2**: Temporal Normalization

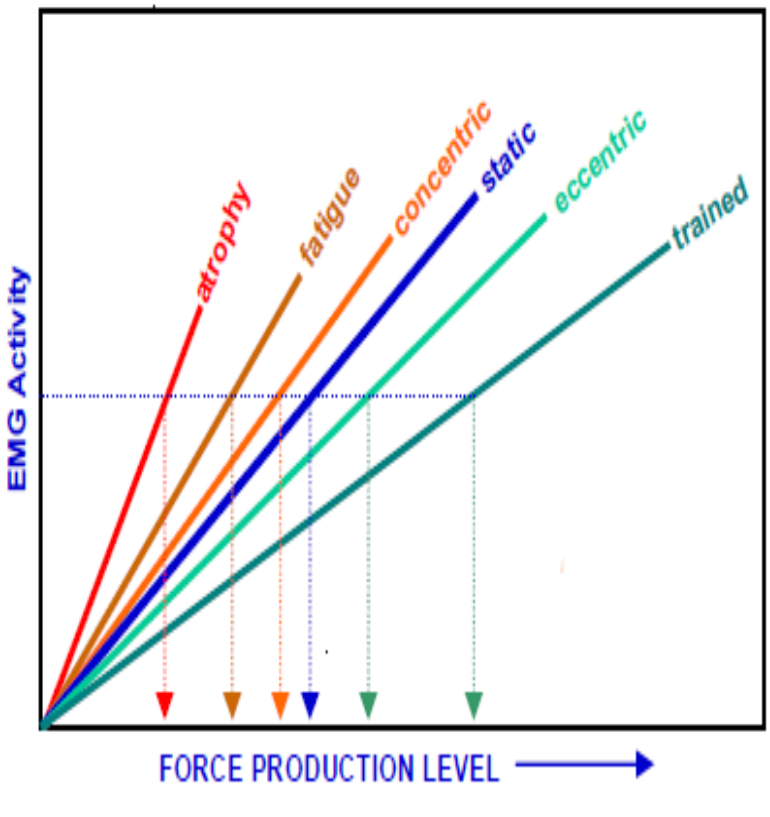

Figure **2.3**: Relationship with Force Produced and EMG Amplitude

3 SYSTEM ARCHITECTURE, DEVICES, TOOLS AND SOLUTIONS

This master thesis study proposes a serious game based rehabilitation tool that uses surface electromyography for lower extremity limbs and it provides a web based feedback module to the physiotherapist that will enable him to monitor remotely his/her patient's performance. Firstly, system architecture is described in this section. BITalino that it is used for sEMG signal acquisition, UNITY Game Engine that is used for game platform and integration of UNITY-BITalino are explained respectively. The selected exercises and games designed for them are presented and finally, feedback module for the physiotherapist is described.

3.1 System Architecture

The proposed system is a serious game concept for the enhancement of motivation of patients and also to give a feedback to physiotherapist for patient follow-up as shown in Figure **3.1**.

The EMG data generated by the patient during exercise, the number of objects collected ; the number of times the player breaks the wall or flies the capsule, and the duration of exercises are all recorded in the database system. After that, EMG signal is analyzed to extract relevant information such as amplitude, power and contractile force. Thus, the physiotherapist is able to follow the development of his/her patient by controlling his/her patient periodically and remotely. Raw EMG data is recorded by the system also and if the physiotherapist wants to access it, he/she can download it via web application.

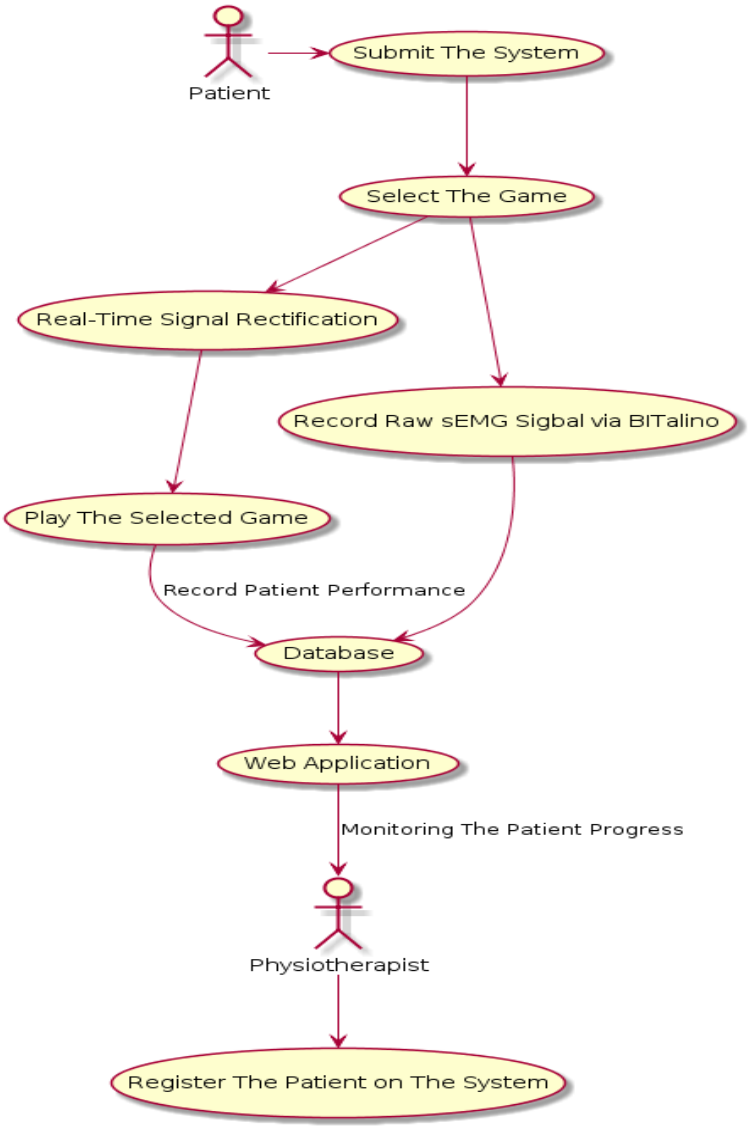

Figure **3.1**: The Proposed System Architecture

3.2 BITalino Device

Devices such as Arduino, Lilypad, Raspberry Pi are used for biosignal acquisition like ECG, EMG etc. In some projects these devices are not sufficient. Because biosignals have different requirements, such as high sampling rate, amplification or resolution. In physiological signal acquisition, inappropriate equipment and high costs are a major problem. BITalino board is recommended to avoid these problems. BITalino is a low-cost device that has biological signal acquisition properties. Specifications of BITalino are shown on the Table **3.1**. In this study, the plugged kit is used for EMG acquisition (Figure **3.2**) (da Silva et al., 2014).

Table**3.1**: The Specifications of BITalino

Sampling Rate.	100, 1000, 1 or 10 Hz
Actuators.	LED
Digital Ports.	4 input (1-bit) + 4 output (1-bit)
Weight.	30 g / 1.06 oz
Size.	105x60 mm / 4.13x2.36 in
Data Link.	Bluetooth (range up to 10m)
Sensors.	EDA ; EMG ; ACC ; LUX ; ECG
Battery.	3.7V Lithium Ion
Analog Ports.	4 input (10-bit) + 2 input (6-bit)

A single channel EMG is used for acquisition from BITalino. The electrodes used are pre-gelled. Acquired EMG signal using BITalino is shown in Figure **3.3**.

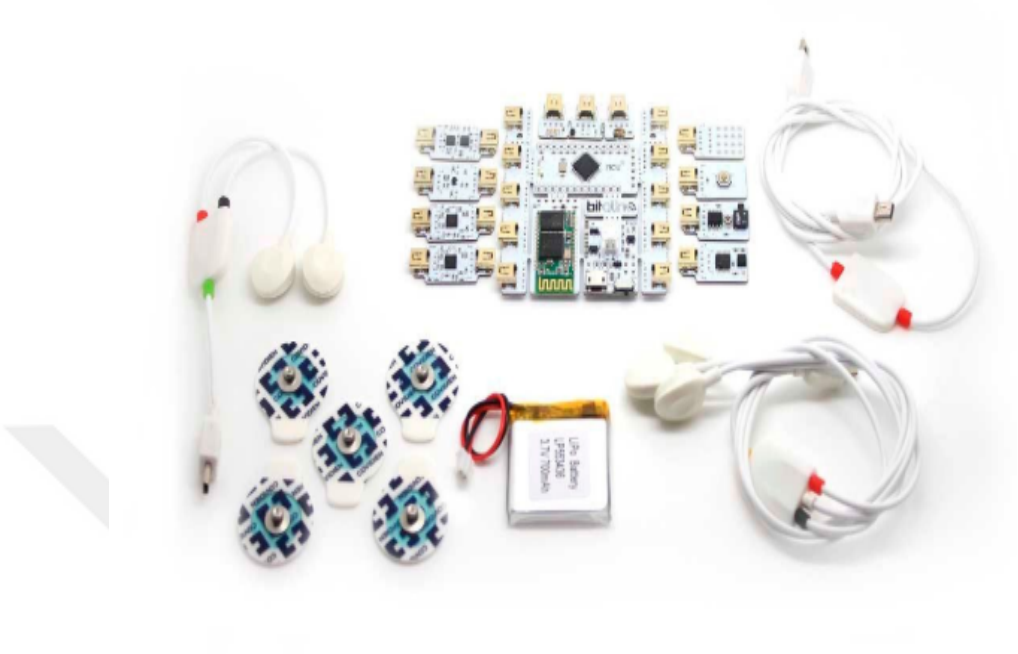

Figure **3.2**: BITalino Plugged Kit. [1]

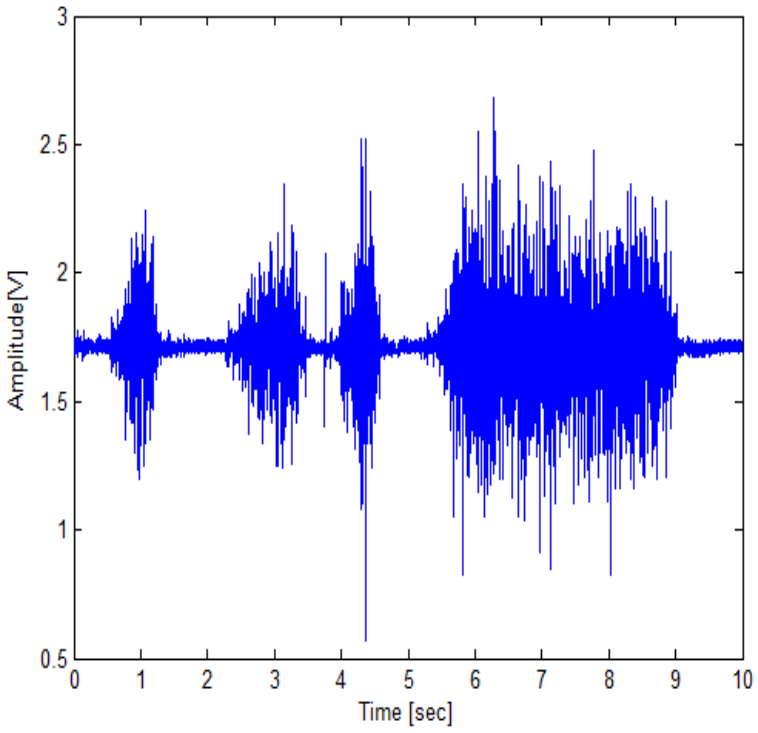

Figure **3.3**: EMG Signal acquired Using BITalino (da Silva et al., 2014)

3.3 UNITY Game Engine

UNITY Game Engine is a powerful and stable tool for designing games [2]. It is a multi-platform free game engine that can also be used for academic purposes. UNITY is chosen as the game engine in this study. Serious game is developed for Windows PC. The documentation of UNITY Game Engine is very good and there are many educational videos, sample projects.

UNITY is a game engine that is created with the C# programming language, but the scripts in UNITY can also be written using different programming languages. In this study, C# programming language is used for scripts.

The "Roll-a-Ball" game in UNITY tutorials is used in this study as the basis for the designed game shown in Figure**3.4**. The aim of the game is to use the arrow keys to move the ball and collect objects to gain points. In this study, instead of the arrow keys, EMG signals received from BITalino in real-time are used as input and changed the game scene according to the gamification protocol. The game is also adaptive according to patients needs as will be explained in detail in the gamification section.

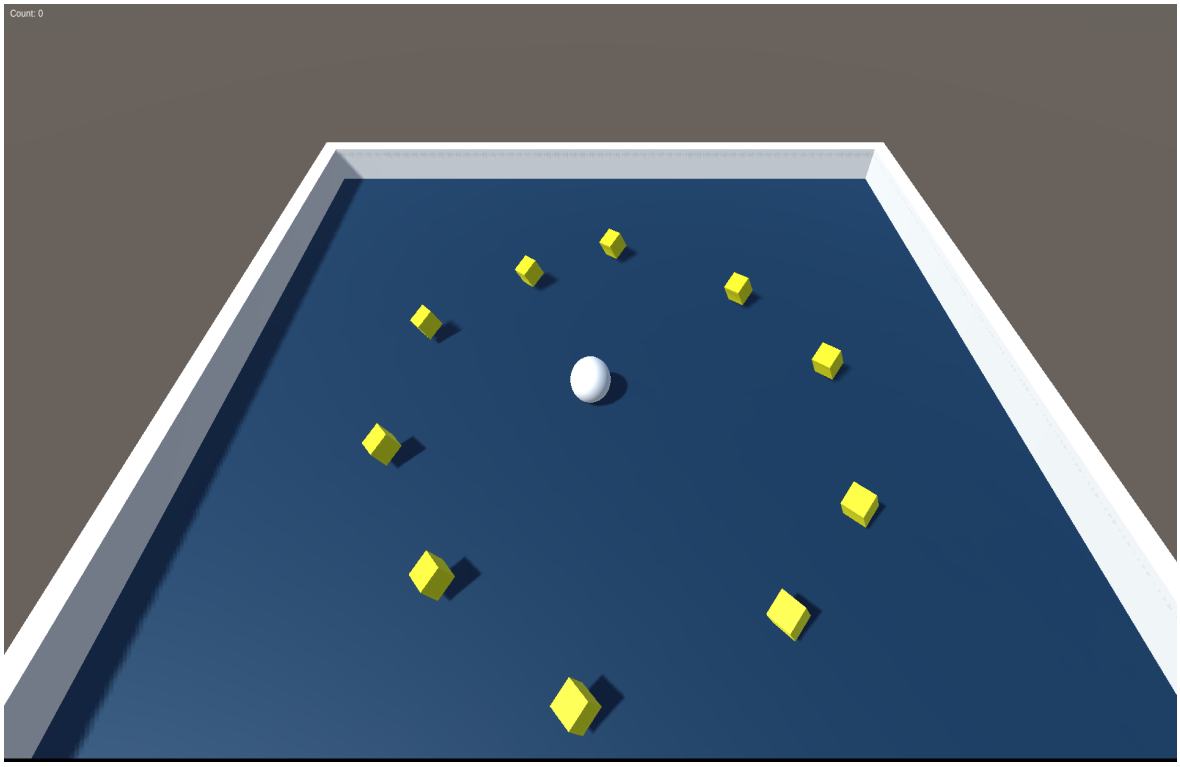

Figure **3.4**: In-Game Image, Roll a Ball [3]

2. https://unity3d.com/

3.4 Integration of UNITY Game Engine And BITalino Device

The integration of UNITY game engine with BITalino is done with the APIs provided On BITalino's web site. [4] [5]

3.5 The Selected Exercises For The System

In this study, the exercises chosen for gamification are active knee extension exercise to strength quadriceps muscle in Figure **3.5**, active knee flexion for hamstring muscles strengthening in Figure **3.6** and terminal extension exercise for vastus medialis obliquus muscle in Figure **3.7** These exercises are recommended for people with muscular atrophy (Edson et al., 2010), (Saka, 2014), (Seto et al., 1989). They are to be repeated 10 times with a wait time of 6 seconds after each repetition.

Lower limb muscles strengthening exercises are selected since there are very few studies on it in the literature although there are a lot of studies about the exercises which are recommended for upper-limb muscles.

3.6 The Placement of Electrodes

The placement of the electrodes is very important for sEMG signal quality (Peters, 2014). Generally, the electrodes are placed at the beginning and end of the relevant muscle, with the grounding electrode being centered between the two electrodes. The electrode positions are shown, for quadriceps and vastus medialis obliquus muscle, in Figure **3.8** and for hamstring muscle in Figure **3.9**.

Usually, the devices which acquire EMG signals measure potential difference of the signal between electrode locations, for this reason the electrodes must be positioned accordingly.

4. `http://bitalino.com/en/development/apis`
5. `https://bitbucket.org/tusistia/bitalinounity3d_c-sdk`

Figure **3.5**: Active Knee Extension Exercise [6]

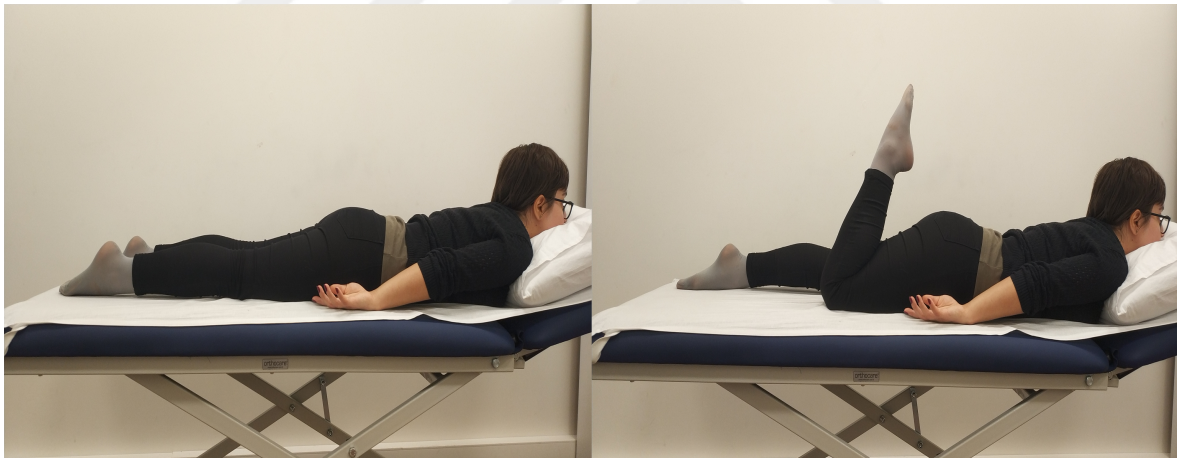

Figure **3.6**: Active Knee Flexion Exercise [7]

Figure **3.7**: Terminal Extension Exercise [8]

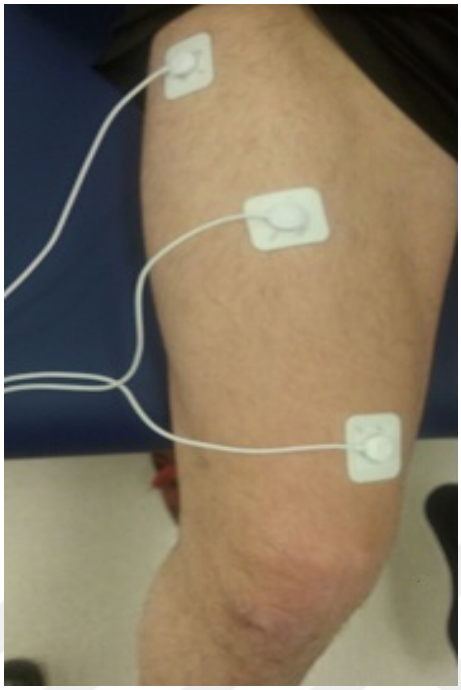

Figure **3.8**: Placement of the Electrodes for Quadriceps and Vastus Medialis Obliquus Muscles [9]

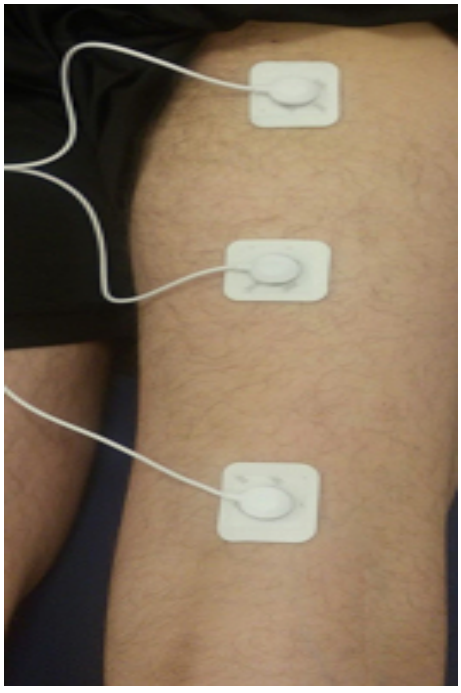

Figure **3.9**: Placement of the Electrodes for the Hamstring Muscle [10]

3.7 The Games Designed For The Selected Exercises

Three different games are designed for three selected exercises, to ensure continuity of treatment participation of patients by gamification. Each exercise is repeated 10 times and at each repetition, the patient will be considered successful if he/she is able to properly contract the muscle during 6 seconds.

There is a start screen in the game. First, the patient has to submit his/her identity number (TCKN), as can be seen in Figure **3.10**. If the patient is in the database, he/she can proceed to the second screen that is the exercise selection menu (Fig.**3.11**). There he/she can select the exercise that he/she wants to play and the game starts.

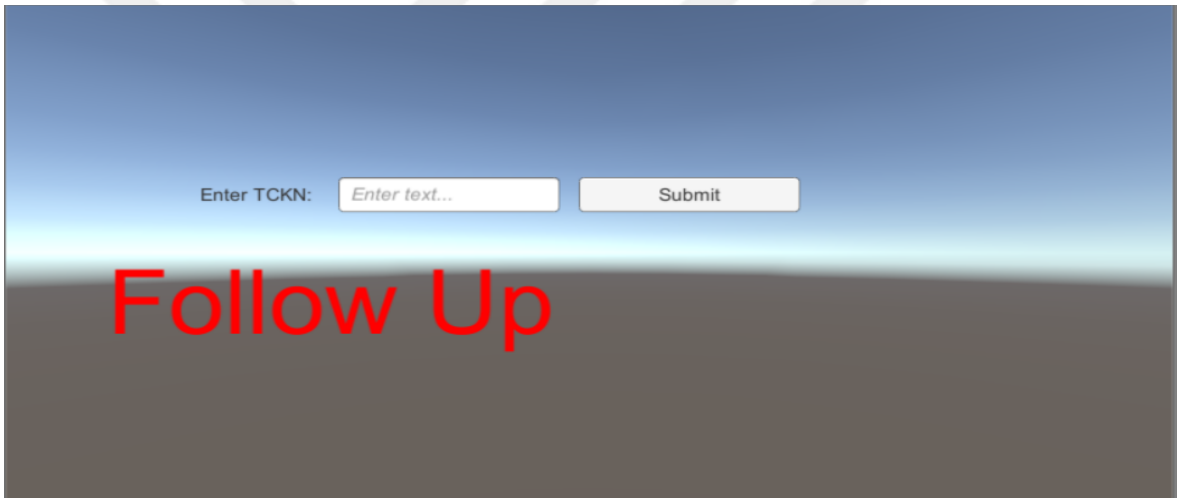

Figure **3.10**: Submit Screen

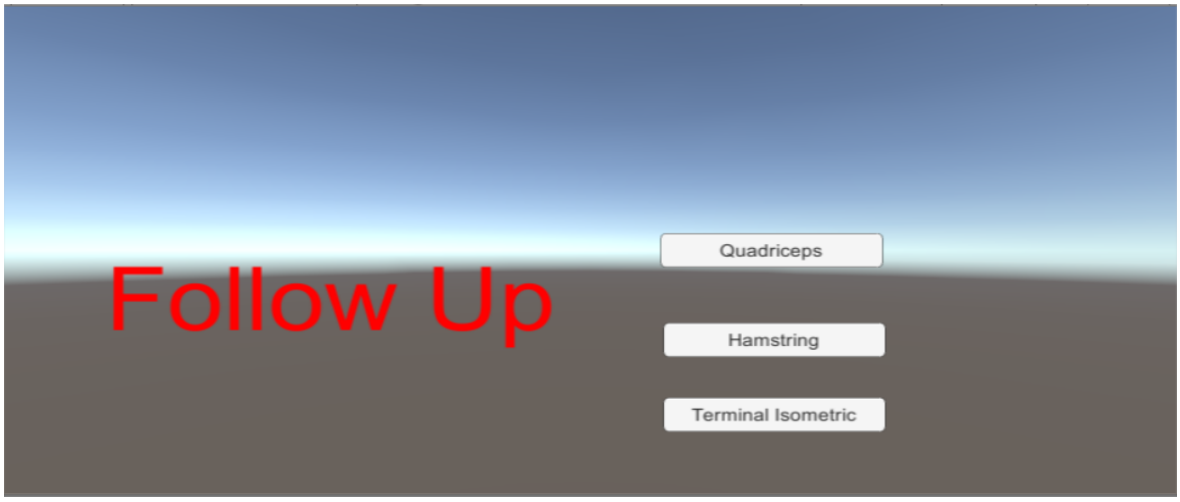

Figure **3.11**: Exercise Selection Menu

3.7.1 Hold The Ball ! (HOBOR) - For Quadriceps Exercise

In this game, there are 10 collectible cubes for each repetitive exercise. If the patient pass the threshold value while exercising and keep it at least at this threshold for 6 seconds, he/she is considered successful so he/she can collect one cube. As the ground is inclined, a barrier appears behind the ball (player) if he/she is successful. Thus the patient has made a full movement (one of the ten repeats). So if the patient collects 10 cubes, the quadriceps exercise ends and the game returns to the main exercise selection screen. It can be seen in-game image in Figure **3.12**. This game is based on "the roll-a-ball" game which is one of the UNITY Game Engine tutorial examples.

3.7.2 Topple The Wall ! - For Terminal Isometric Exercise

This exercise is different from the other two exercises because of it is a kind of exercise which causes muscle contraction without releasing movement. A pendulum mechanics is chosen to use for this exercise. The patient makes the terminal isometric exercise for 6 seconds. During this 6 seconds, the pendulum is stretched. When the time is up, the pendulum is released and hits the wall. The scene is reloaded until 10 exercises are successfully completed. It can be seen in-game image in Figure **3.13**.

3.7.3 Let Fly The Capsule ! - For Hamstring Exercise

For this game, a teeter totter mechanics is used. The initial ball position is slightly in the air due to the game engine mechanics. If the patient pass the threshold maintaining proper contraction for 6 seconds, the ball falls on the teeter totter and so the capsule which is on the other side flies and the patient successfully completes one of 10 repetitive movements. The scene is reloaded until 10 exercises are successfully completed. It can be seen in-game image in Figure **3.14**.

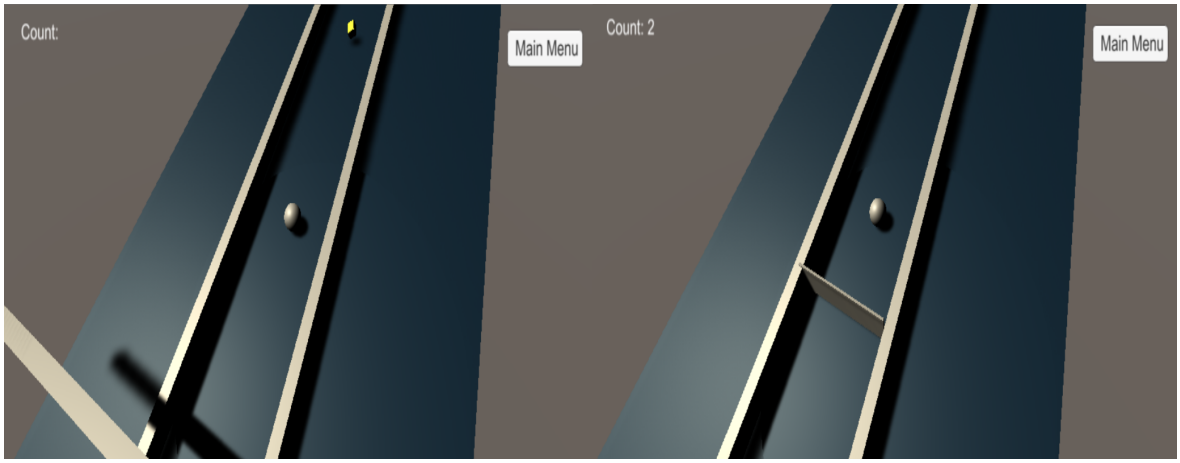

Figure **3.12**: Hold The Ball In-Game Image

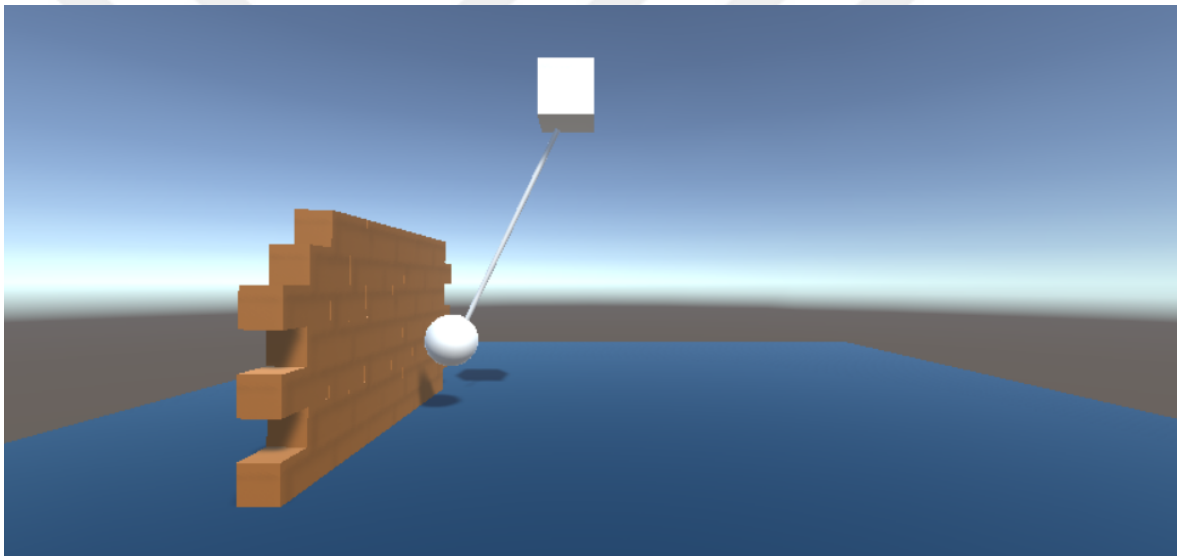

Figure **3.13**: Topple The Wall In-Game İmage

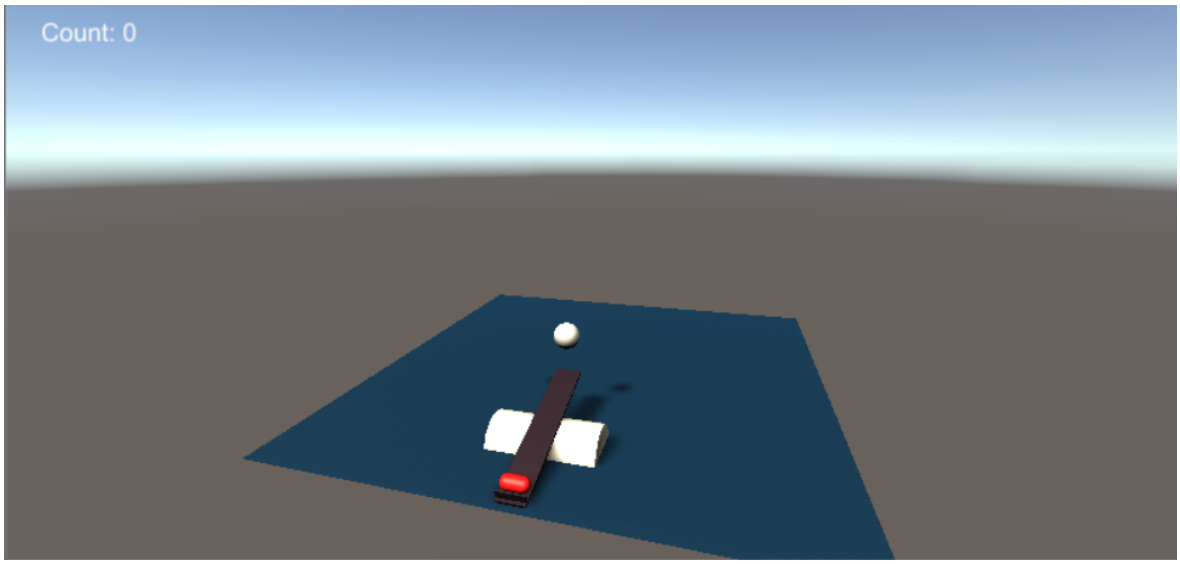

Figure **3.14**: Let Fly The Capsule In-Game İmage

3.8 Feedback Module For The Physiotherapist To Follow His/Her Patients

This module of the system provides important feedback to the physiotherapists. A common problem is the follow-up of the patients for the evaluation of therapy outcomes. The project aims to increase the participation of patients in the treatment with the concept of serious game. The feedback module, helps to facilitate the follow-up of the physiotherapist's patients. In this way, the physiotherapists will be able to monitor the status of their patients at any time, and remotely access the information related to patient's exercise sessions. They will be aware of whether the patients are doing their exercises regularly, their progress according to sessions and time and duration of the exercises.

These features were discussed with physiotherapists and according to their needs, a screen that that it includes session number, exercise name, start and end time is designed.

There exist three screens for physiotherapists referral : one is used to create new patient file ; the second is for the exercises and the third keeps all the patient information. The physiotherapist has to add the new patient on the system otherwise the new patient can not access the games. The screen can be seen in Figure **3.15**. This screen also shows the patients already registered in the system.

The second screen, the exercise screen, lists exercises and relevant information and also a downloadable .csv file that contains the raw EMG data (Figure **3.16**).

Third screen includes detailed patient information and analyses of the exercises. It includes information about patient progress and it helps physiotherapist to comment on the patient. Physiotherapists could see three analysis results for each exercises : amplitude analysis, contractile force of muscle and power analysis thanks to the feedback module (Figure **3.17**).

3.8.1 Relational Database Management Solution - SQLite

SQLite is a lightweight open source relational database management system. Therefore, it is very useful for a computer game system. [11]. SQLite has a big community, so the

11. `https://www.sqlite.org/index.html`

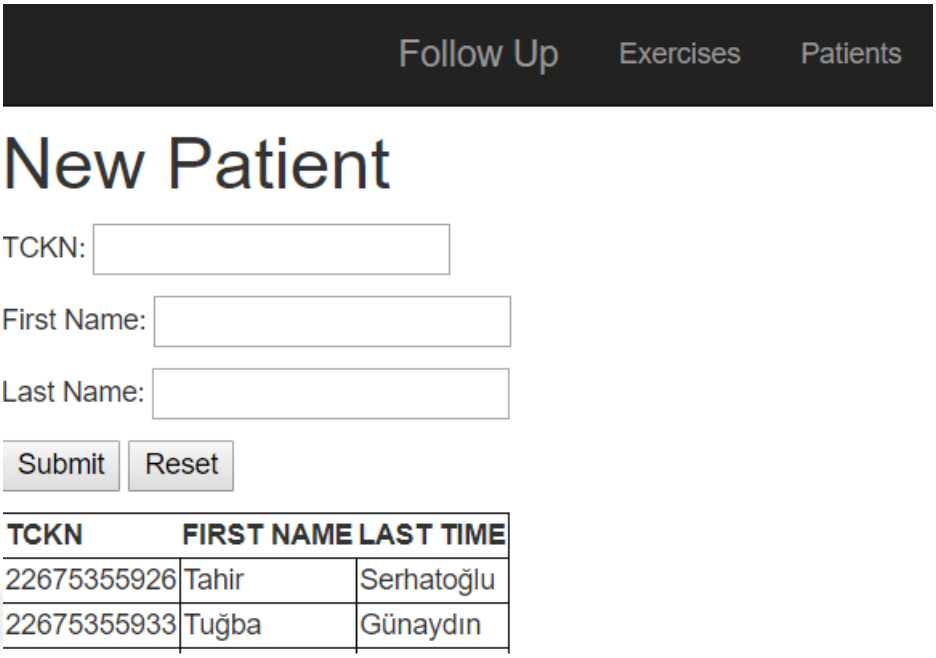

Figure **3.15**: Create New Patient Screen

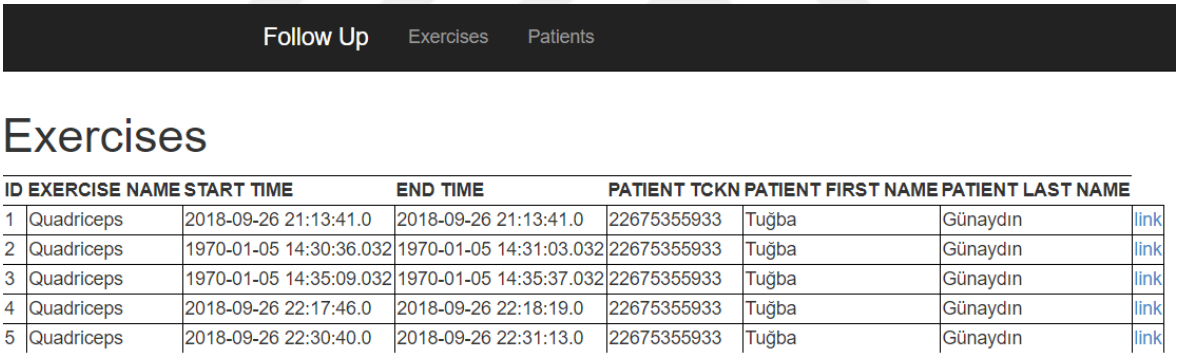

Figure **3.16**: Exercise and Information Screen

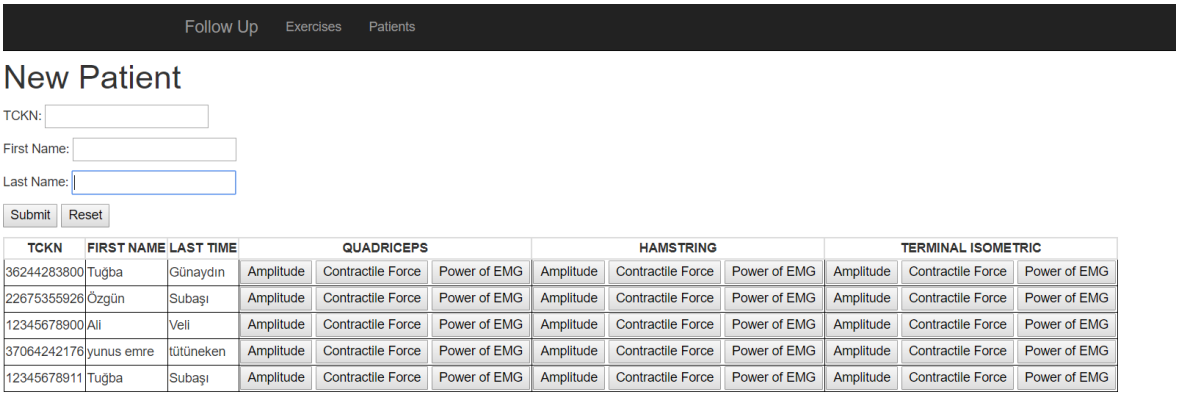

Figure **3.17**: Patient Details–Analyses Of The Exercises

problems encountered can be solved easily. It can be used with easily UNITY and this is another reason for the preference.

3.8.2 Web Application Solution - Spring Framework with Thymeleaf

Spring Framework with Thymeleaf is used to develop a web application for visualization of the patients' data to the physiotherapists. Spring Framework offers an easy integration environment for a ready web application. Thymeleaf is a template solution that is integrated with Spring Framework. It is used for visualization of the web application.

Web application has three screen : new patient screen, exercise screen and patient details screen. The physiotherapists can manage the system and follow-up his/her patients monitoring their data.

4 METHODS

This study offers a solution to two rather important problems in the field of physiotherapy and rehabilitation : to increase the patient's participation in the treatment and to follow the patient remotely with an analysis of patient's data. The techniques, materials and methods used to solve these complex problems are discussed in detail in this section.

4.1 Interviews With Physiotherapists

Physiotherapists were interviewed at every stage of this study for understanding their needs and determining in which cases patients are bored during the treatments. Professors of İstinye University Physiotherapy and Rehabilitation Department, Assistant Professor Nurgül DÜRÜSTKAN ELBAŞI, Associate Professor Yasemin ÇIRAK and Research Assistant Betül BIRIK explained what they need and what do the patients need. Especially, they lend assistance to create goal-oriented games for patients and to create a feedback module for them with EMG data analysis.

Physiotherapists want to know about contractile force of the muscle, amplitude of EMG and power of EMG during the session. They want to see these analysis for each session and progress of all sessions of the patient in an exercise. For instance, suppose that a patient has played the quadriceps exercise 5 times. The physiotherapist wants to see the analysis for each session separately and also he/she wants to see the progress of the patient, that is to say : contractile force of the muscle, amplitude of EMG and power of EMG during all sessions.

An example of the progress of a patient according to sessions of quadriceps exercise by using EMG amplitude analysis values can be seen in Figure **4.1**, by using EMG power analysis values in Figure **4.2** and by using contractile force of muscle analysis values in Figure **4.3**.

The progress in terminal isometric exercise is shown for EMG amplitude analysis values in Figure **4.4**, for EMG power analysis values in Figure **4.5** and for contractile force of muscle analysis values in Figure **4.6**. Same progress can be observed in hamstring exercise for EMG amplitude analysis values in Figure **4.7**, for EMG power analysis values in Figure **4.8** and for contractile force of muscle analysis values in Figure **4.9**.

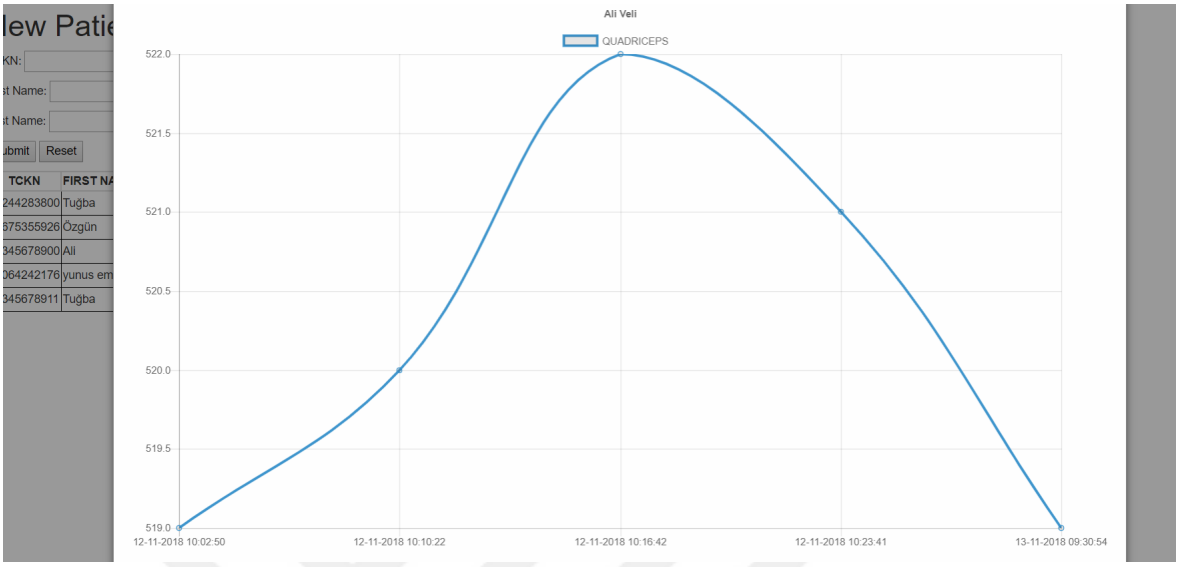

Figure **4.1**: An Example Graph of Progress of A Patient According to Sessions by Amplitude of EMG Analysis, Quadriceps Exercises

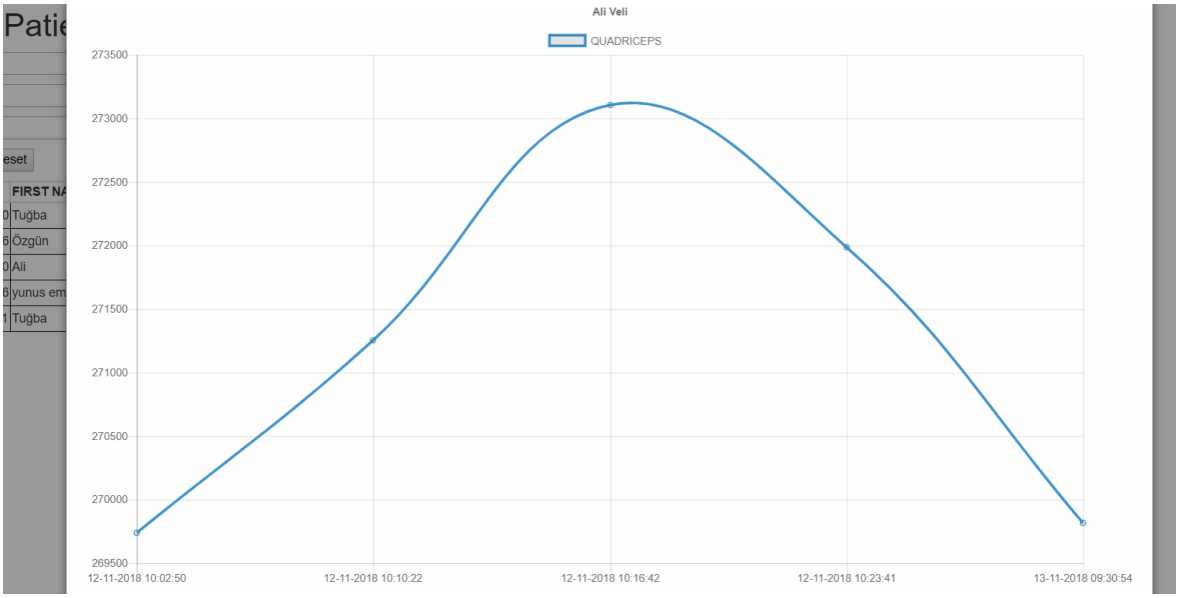

Figure **4.2**: An Example Graph of Progress of A Patient According to Sessions by Power of EMG Analysis, Quadriceps Exercises

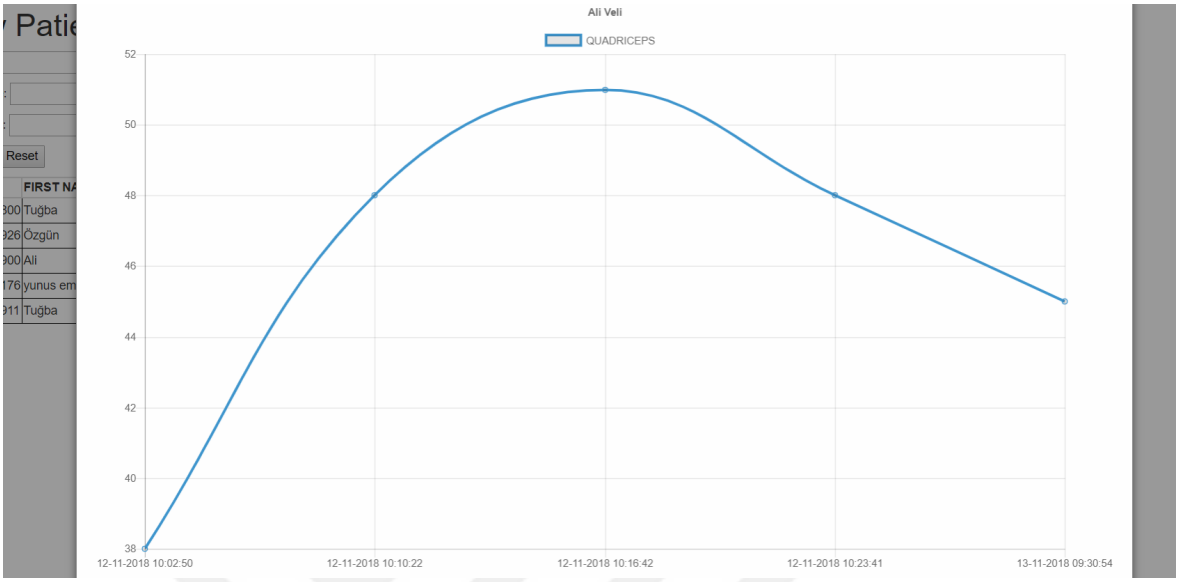

Figure **4.3**: An Example Graph of Progress of A Patient According to Sessions by Contractile of Muscle of EMG Analysis, Quadriceps Exercises

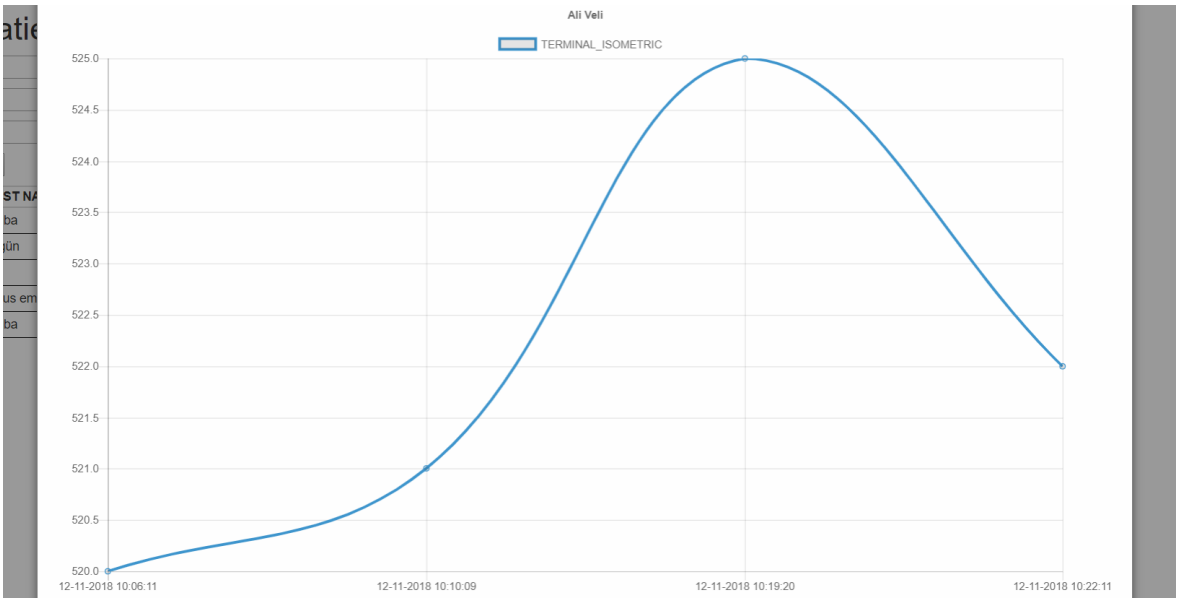

Figure **4.4**: An Example Graph of Progress of A Patient According to Sessions by Amplitude of EMG Analysis, Terminal Isometric Exercises

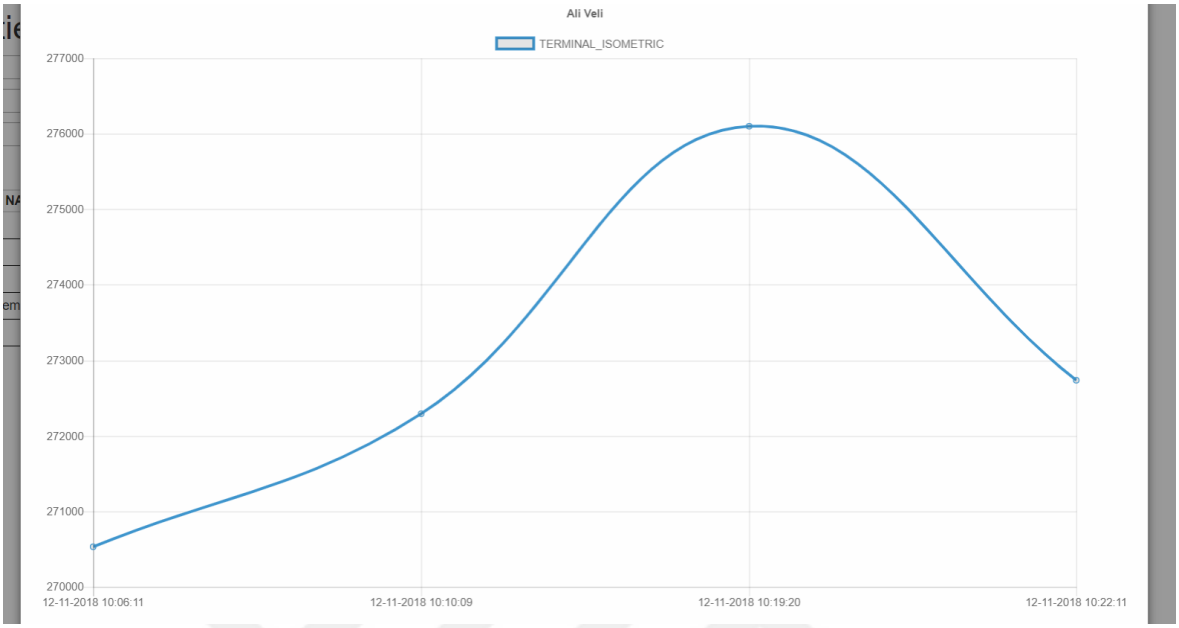

Figure **4.5**: An Example Graph of Progress of A Patient According to Sessions by Power of EMG Analysis, Terminal Isometric Exercises

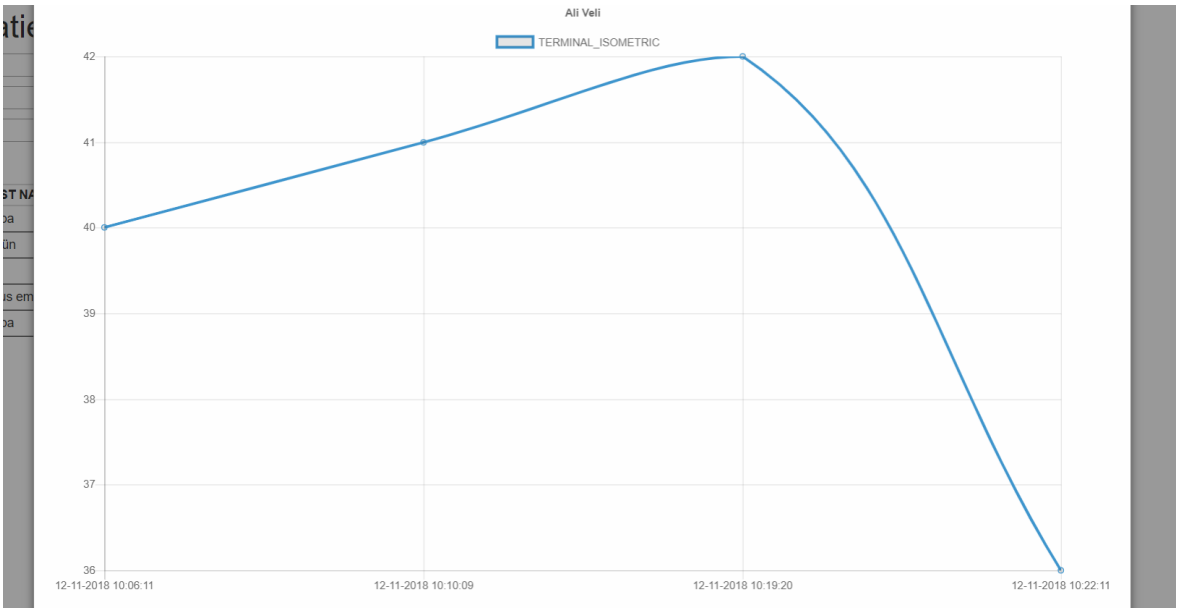

Figure **4.6**: An Example Graph of Progress of A Patient According to Sessions by Contractile of Muscle of EMG Analysis, Terminal Isometric Exercises

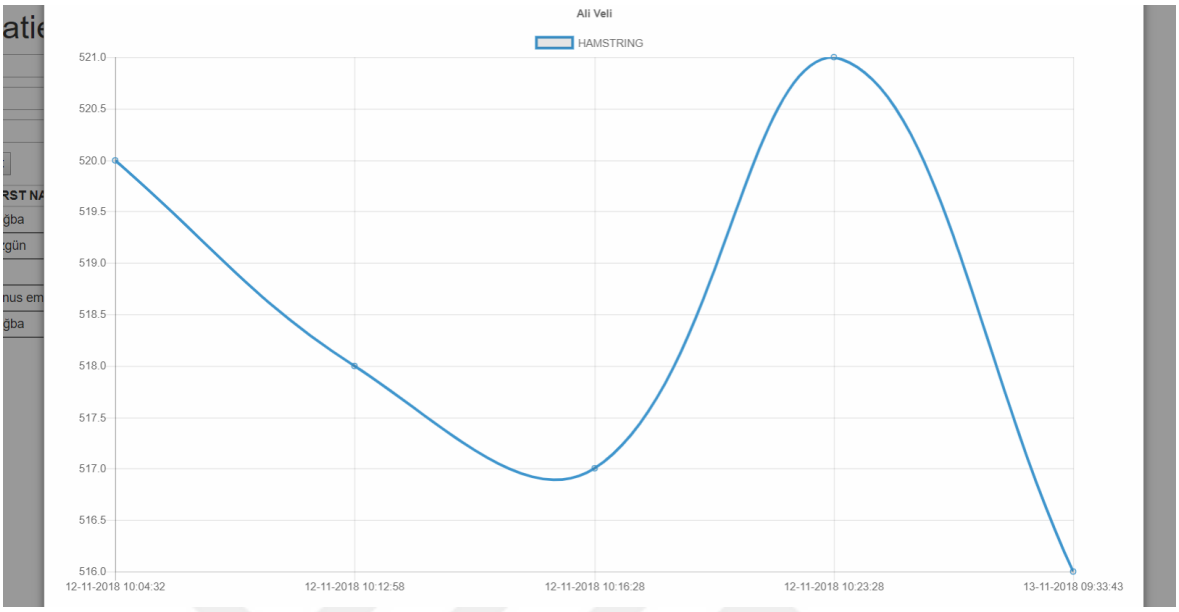

Figure **4.7**: An Example Graph of Progress of A Patient According to Sessions by Amplitude of EMG Analysis, Hamstring Exercises

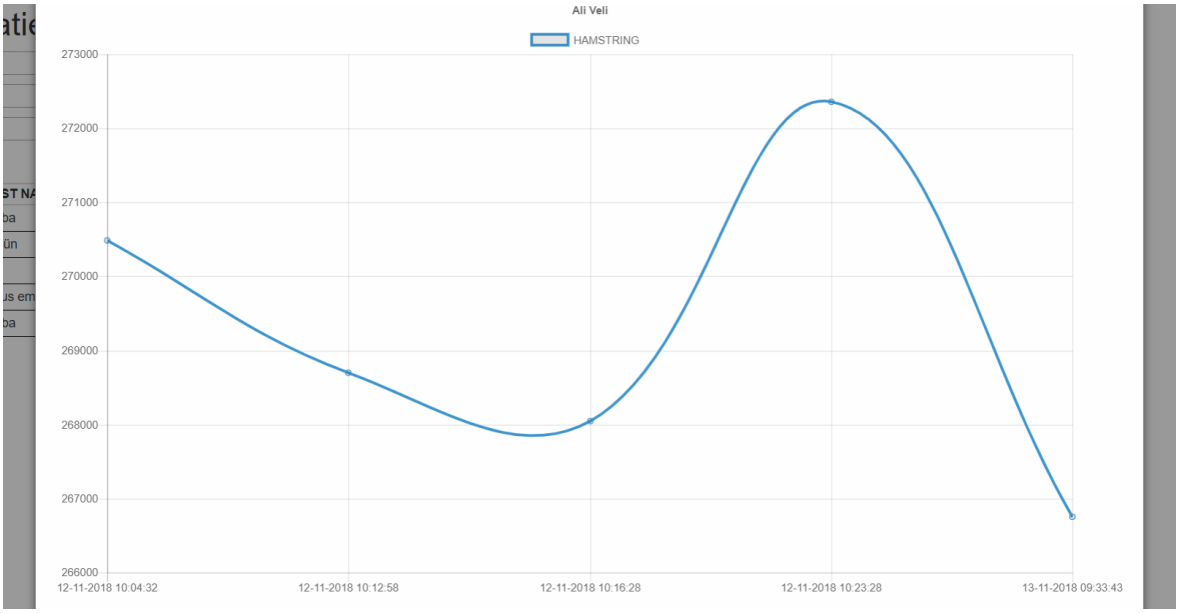

Figure **4.8**: An Example Graph of Progress of A Patient According to Sessions by Power of EMG Analysis, Hamstring Exercises

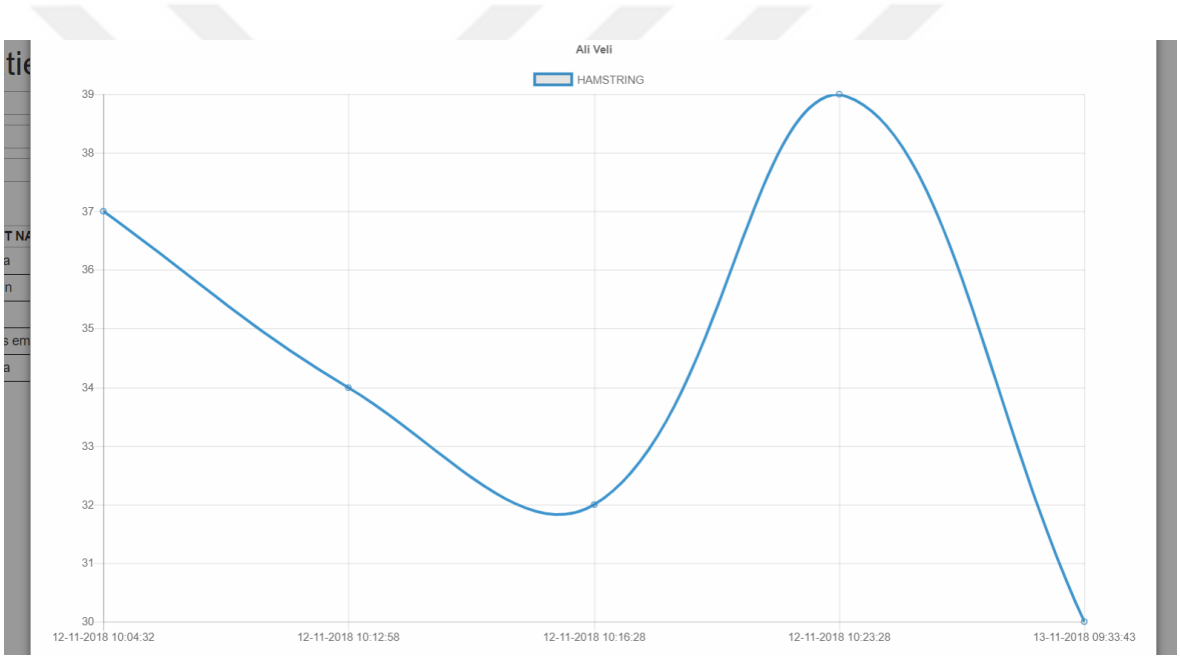

Figure **4.9**: An Example Graph of Progress of A Patient According to Sessions by Contractile of Muscle of EMG Analysis, Hamstring Exercises

4.2 Collecting Data From Healthy Volunteers And Patients

The data are collected from 8 healthy volunteers and 3 patients for understanding EMG signal, developing game controller module and analyzing data. Healthy volunteers are those who have no operation on the lower-limbs and do not need to perform muscle strengthening exercises that are used in this study. On the other side, the patients have an operation on the lower-limbs and physical therapy and rehabilitation specialists recommend muscle strengthening exercises that are used in this study to them.

Healthy volunteers perform the exercises with their dominant leg (left or right leg) as repeating 10 times and each time they contract the relevant muscle during 6 seconds for three exercises without playing the games (in other words traditional method). The patients perform these exercises with their problematic leg, repeating 10 times, 6 seconds, traditional method.

One of healthy volunteer subjects (healthy subject 3) is a former athlete. He/she participated in the races professionally for many years. The other healthy volunteer subjects are ordinary, i.e performs normal physical activities. One of patient volunteer subjects is a semi professional football player who he/she underwent anterior cruciate ligament surgery on his/her dominant leg. The other patient volunteer subjects are ordinary and the second one had a knee cover shift surgery (i.e patella surgery) and the third one had a hip replacement surgery. Both of two had undergone surgery on the dominant side.

4.3 Calibration Method For Rectification of EMG Real-Time

In the game part, the EMG signal is acquired in real-time thanks to UNITY-BITalino integration, it is mentioned earlier. Acquired EMG signal varies according to environment state. A simple rectification method is used to eliminate this noise and to acquire a more clear EMG signal is aimed. Patient has to do this in the beginning of the each exercises. After placed electrodes correctly and starts the game, during 20 seconds, the patient do not exercise but system acquires the signals and calculates sum of absolute values of EMG signal from frame by frame, get an average of this sum is calculated and is kept. During 20 seconds, it is calculated for every frames and sum of each average is calculated also and a more average value is found. In this way, the noise of environ-

ment is found out, i.e calibration value. After that, the difference of real-time data value and the calibration value is the actual value of EMG. According to this value, patient controls the game. The algorithm of calibration method can be seen in Algorithm 1. It is based on the method of Adrien Verhulst & Paulin Doux LARIS-ISTIA.

Algorithm 1: Calibration Method Algorithm

```
Data : BITalino signals;
while CalibrationSeconds do
    for Each Frame do
        Read as much as you can from BITalino;
        Take average of BITalino data;
    end
    Take average of Frames;
end
```

4.4 Feature Extraction Methods

Feature extraction methods are used for classifying the data, for extracting some information from the data and for understanding the data. In the literature, there are several feature extraction methods for EMG signals. Three different methods are used in this study : Root Mean Square (RMS) in equation 4.1, Mean Absolute Value/Deviation (MAV or MAD) in equation 4.2 and Variance of EMG (VAR) in equation 4.3 where N is the length of EMG and S_n is signal in a cell. RMS is used for analyzing amplitude of EMG, MAD is used for analyzing contractile force of muscle and VAR is used for analyzing power of EMG signals.

$$RMS = \sqrt[2]{\frac{1}{N}\sum_{n-1}^{N} S_n^2} \tag{4.1}$$

$$MAD = \frac{1}{N}\sum_{n-1}^{N} |S_n - average| \tag{4.2}$$

$$VAR = \frac{1}{N}\sum_{n-1}^{N} S_n^2 \tag{4.3}$$

4.5 User Feedback Survey

There are some principle scientific studies in the literature in order to measure parameters such as acceptance, usefulness and ease of use of a new technological product. Based on the principle articles of Davis (Davis, 1989), Shin (Shin, 2007), Kim and Shin (Kim and Shin, 2015) two different surveys are prepared for measuring perceived usefulness and perceived ease of use. Attitude and intention of use are measured also based on the article of Venkatesh et al. (Venkatesh et al., 2003) through these two survey. The surveys are discussed in detail below. In addition, the Turkish translation of the surveys for users is presented as an appendix.

4.5.1 The Survey For Physiotherapist

As mentioned before, the Follow-Up system consists of 2 basic parts : Games for patients and Feedback Module for physiotherapists. In this section, the survey questions to the physiotherapists for the feedback module test are explained. The survey of Feedback Module is consisted of 4 parts : Perceived usefulness, perceived ease of use, attitude and intention to use. Perceived usefulness survey questions are in Table **4.1**, perceived ease of use survey questions are in Table **4.2**, attitude survey questions are in Table **4.3** and finally, intention to use survey questions are in Table **4.4**.

Table**4.1**: Perceived Usefulness Survey Questions For Physiotherapists

Feedback module of Follow-Up system is very useful to follow-up the patient remotely in general.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Feedback module of Follow-Up system provides very useful service and information to me.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Feedback module of Follow-Up system improves the quality of the job I do.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Feedback module of Follow-Up system increases my productivity.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Feedback module of Follow-Up system enhances my effectiveness on the job.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

4.5.2 The Survey For Patients

To increase patient participation in long-term and boring physiotherapy and rehabilitation therapy, lower-extremity muscle strengthening exercises (quadriceps exercise, terminal isometric exercise and hamstring exercise) were turned into computer games previously mentioned. The users play the three games and they are asked questions about the comparison of traditional methods and game experience. The questions for evaluating games for users are prepared using the same scales as the questions asked for the physiotherapists to evaluate the feedback module. Perceived usefulness survey questions for patients are in Table **4.5**, perceived ease of use survey questions for patients are in Table **4.6**, attitude survey questions for patients are in Table **4.7** and finally, intention of use survey questions for patients are in Table **4.8**.

Table**4.2**: Perceived Ease of Use Survey Questions For Physiotherapists

Operating feedback module of Follow-Up system is easy for me.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I find feedback module of Follow-Up system easy to use.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Using feedback module of Follow-Up system does not require a lot of my mental effort.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.3**: Attitude Survey Questions For Physiotherapists

Using feedback module of Follow-Up system is a better idea than traditional patient follow-up methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I have a generally more favorable attitude toward using feedback module of Follow-Up system than traditional patient follow-up methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I like the idea of using feedback module of Follow-Up system more than traditional patient follow-up methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Overall, using feedback module of Follow-Up system is more beneficial than traditional patient follow-up methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.4**: Intention To Use Survey Questions For Physiotherapists

I predict I will use feedback module of Follow-Up system in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I plan to use feedback module of Follow-Up system in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I expect my use of Follow-Up system to continue in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.5**: Perceived Usefulness Survey Questions For Patients

Playing the games of Follow-Up system are very useful to motivate me to increase participation in treatment in general.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Playing the games of Follow-Up system improve the quality of the treatment I do.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Playing the games of Follow-Up system increase my participation in treatment.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Playing the games of Follow-Up system enhance my effectiveness in the treatment.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.6**: Perceived Ease Of Use Survey Questions For Patients

Playing the games of Follow-Up system makes it easier for me to do my exercises.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I find the games of Follow-Up system easy to play.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Playing the games of Follow-Up system does not require a lot of my mental effort.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.7**: Attitude Survey Questions For Patients

Playing the games of Follow-Up system is a better idea than exercising with traditional treatment methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I have a generally more favorable attitude toward playing the games of Follow-Up system than exercising with traditional treatment methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I like the idea of playing the games of Follow-Up system more than exercising with traditional treatment methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
Overall, playing the games of Follow-Up system is more beneficial than exercising with traditional treatment methods.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

Table**4.8**: Intention To Use Survey Questions For Patients

I predict I will play the games of Follow-Up system in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I plan to play the games of Follow-Up system in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)
I expect to play of the games of Follow-Up system to continue in the future.				
Definitely I Agree (5)	I Agree (4)	Neither Agree Nor Disagree (3)	I Disagree (2)	Definitely I Disagree (1)

5 RESULTS

5.1 sEMG Data Analysis Results

sEMG values are collected by using BITalino device with 1000 sampling rate and single channel from 8 healthy and 3 patient volunteers, each exercise repeated 10 times and during 6 seconds on contraction of muscle. Afterwards, feature extraction methods are applied on the data that are explained in the previous section. Feature extraction methods were used in this study to provide feedback to the physiotherapist by performing EMG analysis. Results of quadriceps exercise records in Table **5.1**, results of terminal isometric exercise records in Table **5.2** and finally, results of hamstring exercise records in Table **5.3** for every subjects.

Table**5.1**: Feature Extraction Methods Results of Quadriceps Exercise

Subject	RMS Values	MAD Values	VAR Values
Healthy Subject 1	516.339922811	36.3461009486	266606.915888
Healthy Subject 2	514.270298530	16.9532957229	264473.93995
Healthy Subject 3	528.758214127	64.1916172977	279585.249007
Healthy Subject 4	514.397057882	19.521919791	264604.333157
Healthy Subject 5	514.56158606	20.8043497099	264773.625848
Healthy Subject 6	515.746494384	30.7424655647	265994.446469
Healthy Subject 7	521.730745682	62.8383326812	272202.970989
Healthy Subject 8	515.720645376	30.7441031619	265967.784067
Patient Subject 1	514.777448453	21.7142738835	264995.821436
Patient Subject 2	514.067140575	3.18200845887	264265.025019
Patient Subject 3	513.985031993	2.94810092619	264180.613112

The EMG data generated during each exercise is distinctive. This is due to the fact that the EMG signals are acquired from different muscles and are obtained when different exercises are performed. In Figure **5.3**, active knee extension for quadriceps muscle

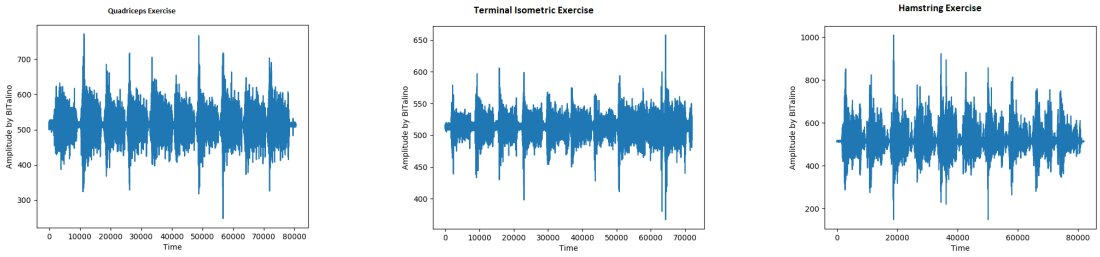

Figure **5.1**: Healthy Subject 2 Data Plot

Table**5.2**: Feature Extraction Methods Results of Terminal Isometric Exercise

Subject	RMS Values	MAD Values	VAR Values
Healthy Subject 1	517.373494809	15.4555369165	267675.333131
Healthy Subject 2	513.760493756	6.61156735802	263949.844944
Healthy Subject 3	522.135102847	58.695262838	272625.065625
Healthy Subject 4	513.867181614	8.76021773812	264059.48034
Healthy Subject 5	513.702507477	5.02592386717	263890.266189
Healthy Subject 6	514.152844893	14.6638579898	264353.147912
Healthy Subject 7	515.472481482	29.7743946631	265711.879165
Healthy Subject 8	514.026681484	13.165012324	264223.429277
Patient Subject 1	514.464045808	14.8675639362	264673.254429
Patient Subject 2	513.848533044	1.52304688714	264040.314912
Patient Subject 3	513.989406077	3.45558018479	264185.10956

Table**5.3**: Feature Extraction Methods Results of Hamstring Exercise

Subject	RMS Values	MAD Values	VAR Values
Healthy Subject 1	515.006023737	24.2842156226	265231.204486
Healthy Subject 2	514.944534953	22.2157802776	265167.874078
Healthy Subject 3	514.723039735	20.7552857527	264939.807634
Healthy Subject 4	513.921903833	11.1823845291	264115.723239
Healthy Subject 5	513.952141035	11.2699946809	264146.803274
Healthy Subject 6	518.700381036	20.9385386271	269050.085286
Healthy Subject 7	515.446785454	28.0310802827	265685.388635
Healthy Subject 8	515.311435499	24.060173659	265545.875556
Patient Subject 1	519.050718121	51.2630424901	269413.647982
Patient Subject 2	514.852781297	1.88303263765	265073.386409

EMG data plot, in Figure **5.4** terminal extension exercise for vastus medialis obliquus muscle EMG data plot and finally, in Figure **5.5** active knee flexion exercise for hamstring muscle is presented. Additionally, it can be seen obtained sEMG data plot from healthy subject 2 with three exercise in Figure **5.1** and from patient subject 2 with three exercises in Figure **5.2**.

All collected data is analyzed according to exercise and feature extraction methods, RMS, MAD, VAR. The RMS results of Active Knee Extension Exercise (Quadriceps Exercise) could be seen in Figure **5.6**. The MAD results of Active Knee Extension Exercise (Quadriceps Exercise) could be seen in Figure **5.7** and the last analysis for Active Knee Extension Exercise (Quadriceps Exercise), the VAR results of Active Knee Extension Exercise (Quadriceps Exercise) could be seen in Figure **5.8**. The RMS results of Terminal Extension Exercise (Terminal Isometric Exercise) could be seen in Figure

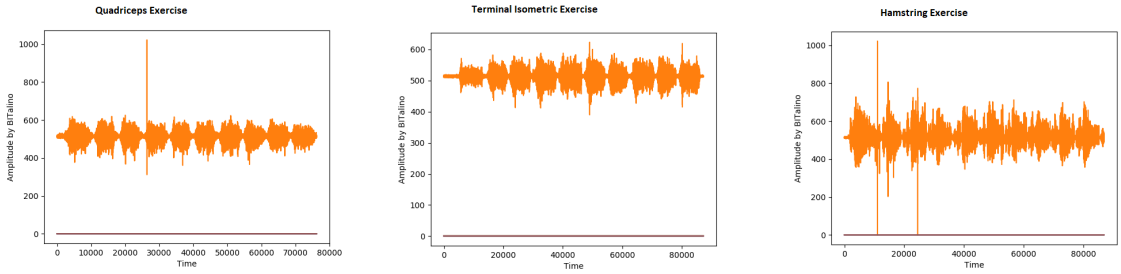

Figure **5.2**: Patient Subject 2 Data Plot

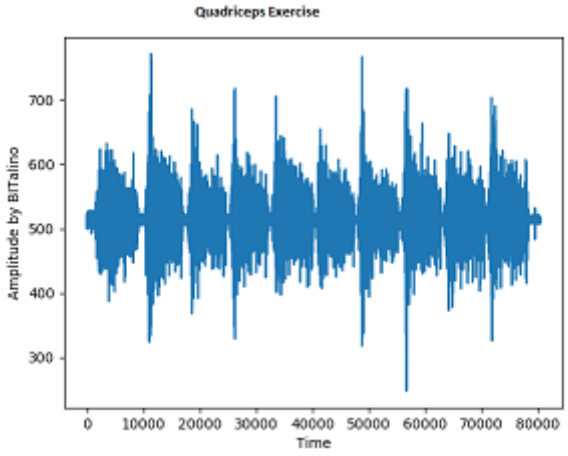

Figure **5.3**: Active Knee Extension Exercise (Quadriceps Exercise) Recorded EMG

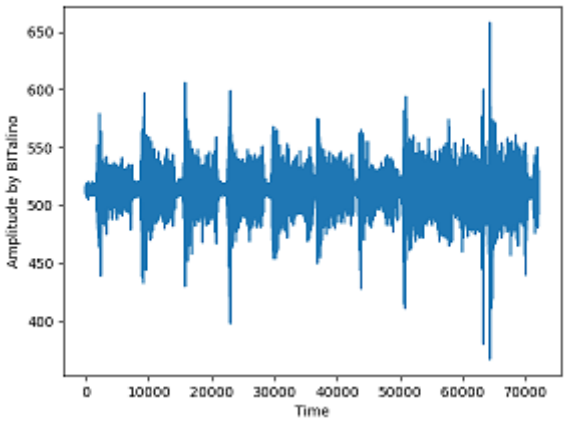

Figure **5.4**: Terminal Extension Exercise (Terminal Isometric Exercise) Recorded EMG

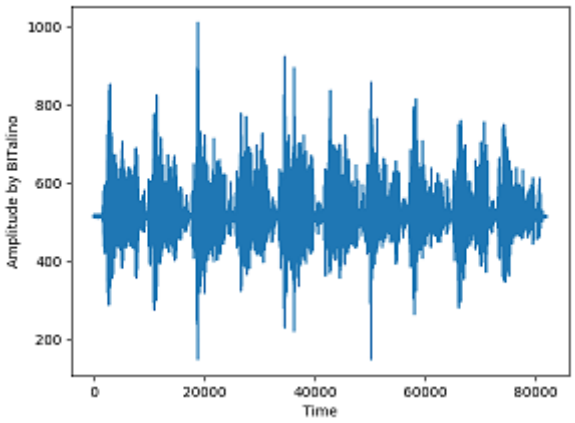

Figure **5.5**: Active Knee Flexion Exercise (Hamstring Exercise) Recorded EMG

5.9. The MAD results of Terminal Extension Exercise (Terminal Isometric Exercise) could be seen in Figure **5.10** and the last analysis for Terminal Extension Exercise (Terminal Isometric Exercise), the VAR results of Terminal Extension Exercise (Terminal Isometric Exercise) could be seen in Figure **5.11**. Finally, the RMS results of Active Knee Flexion Exercise (Hamstring Exercise) could be seen in Figure **5.12**. The MAD results of Active Knee Flexion Exercise (Hamstring Exercise) could be seen in Figure **5.13** and the last analysis for Active Knee Flexion Exercise (Hamstring Exercise), the VAR results of Active Knee Flexion Exercise (Hamstring Exercise) could be seen in Figure **5.14**.

EMG analysis results vary according to physical condition of the subject and medical history. The characteristics of the subjects were mentioned in the previous section. In this section, the variation of EMG analysis of different subjects is explained according to their characteristics. For this comparison study, the data analysis of two healthy and patient subjects were used. Healthy subject 2 and patient subject 2 are ordinary volunteer subjects and healthy subject 3 and patient subject 1 are sportive subjects. These four EMG analysis are compared by RMS, MAD and VAR values for each exercises. The quadriceps exercises comparison results could be seen in Figures **5.15**, **5.16**, **5.17**. The terminal isometric exercises comparison results could be seen in Figures **5.18**, **5.19**, **5.20**. And finally, the hamstring exercises comparisons results could be seen in Figures **5.21**, **5.22**, **5.23**.

When the results of benchmarking are analyzed it is cleared that all of the features of healthy subject 3 for quadriceps and terminal isometric exercises has the leading results. When the analysis results of these two exercises are examined, it is cleared

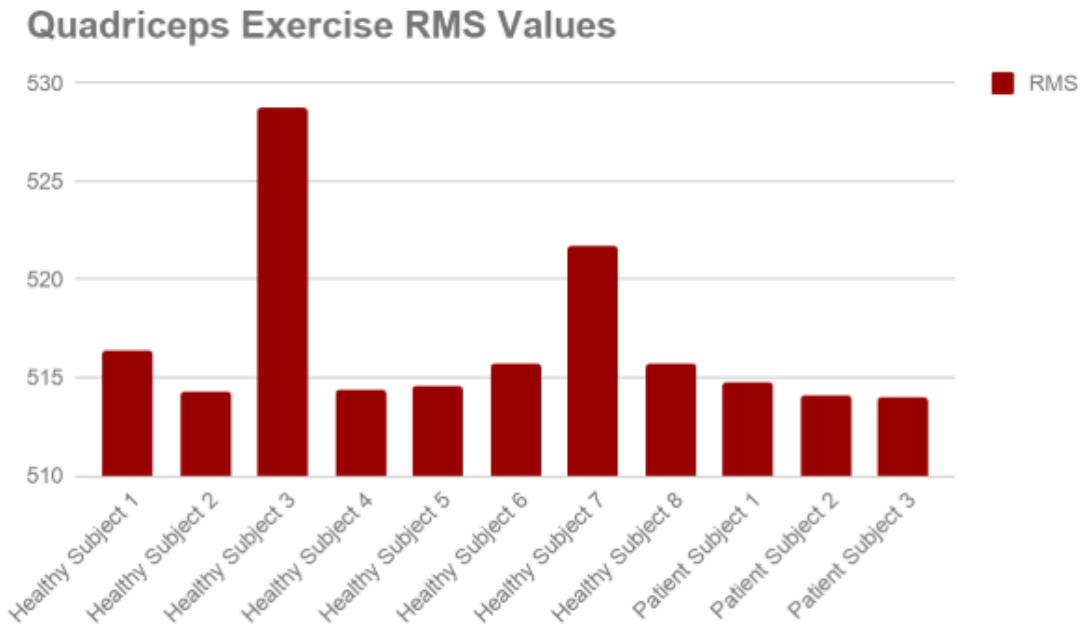

Figure **5.6**: The RMS Analysis Results of Active Knee Extension Exercise (Quadriceps Exercise) For All Subjects

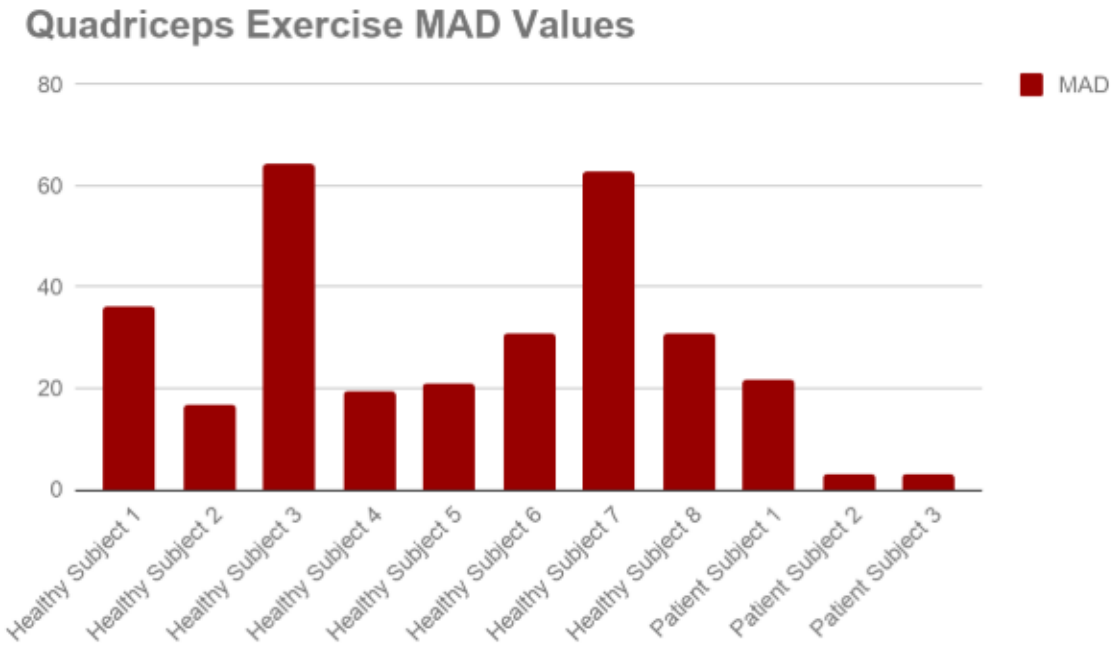

Figure **5.7**: The MAD Analysis Results of Active Knee Extension Exercise (Quadriceps Exercise) For All Subjects

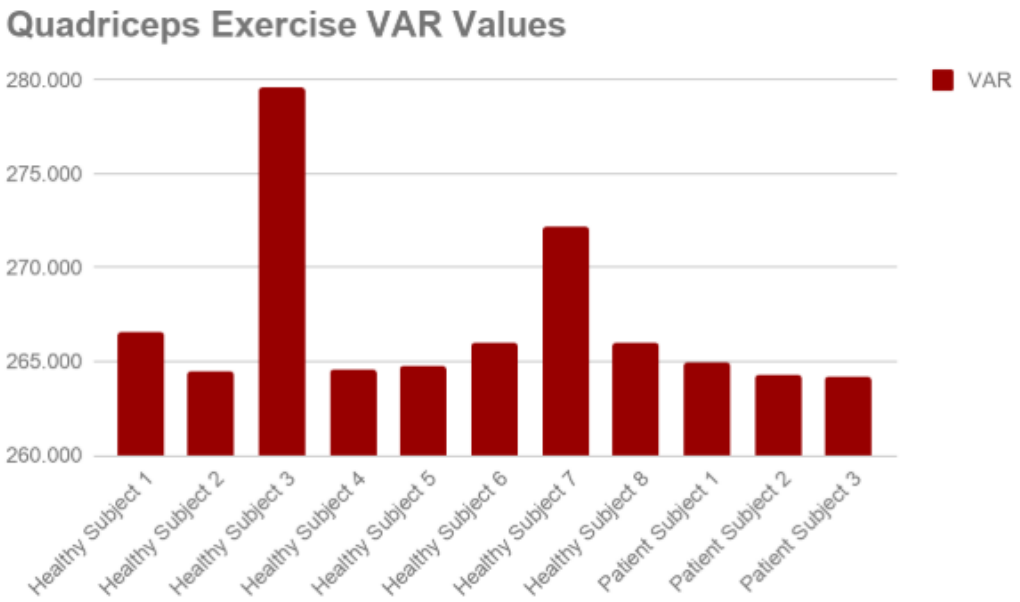

Figure **5.8**: The VAR Analysis Results of Active Knee Extension Exercise (Quadriceps Exercise) For All Subjects

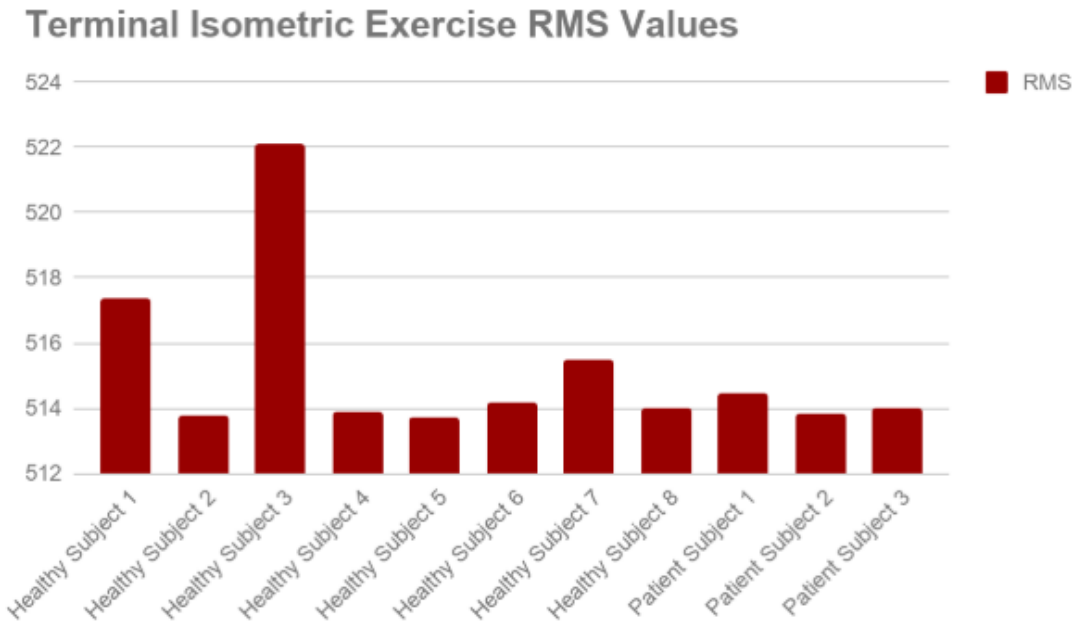

Figure **5.9**: The RMS Analysis Results of Terminal Extension Exercise (Terminal Isometric Exercise) For All Subjects

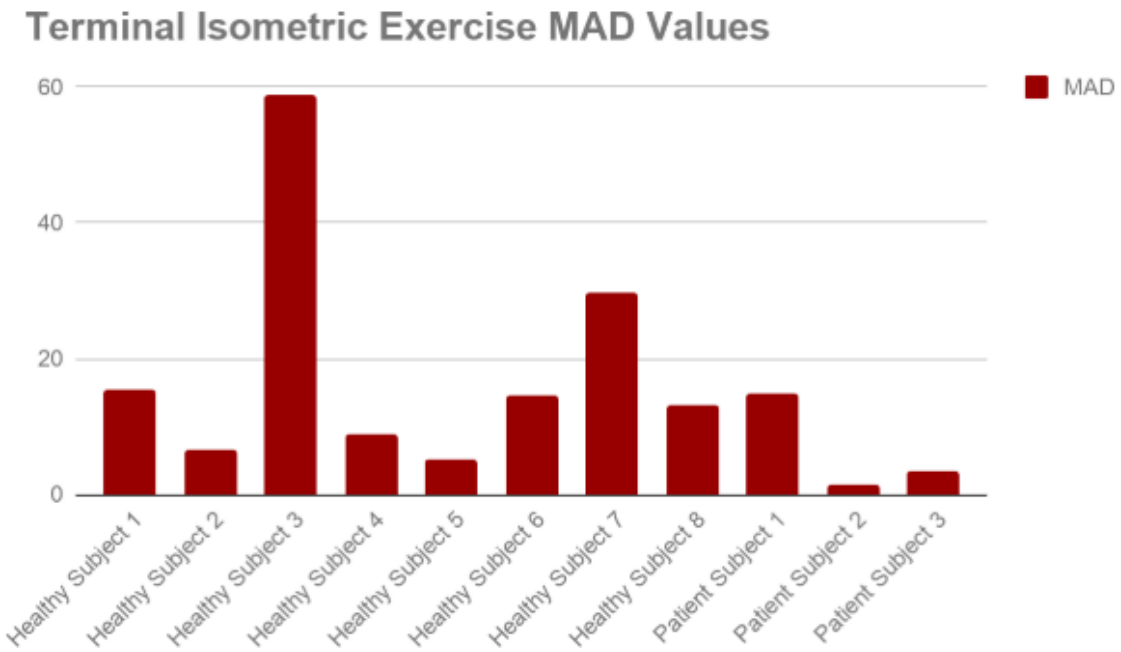

Figure **5.10**: The MAD Analysis Results of Terminal Extension Exercise (Terminal Isometric Exercise) For All Subjects

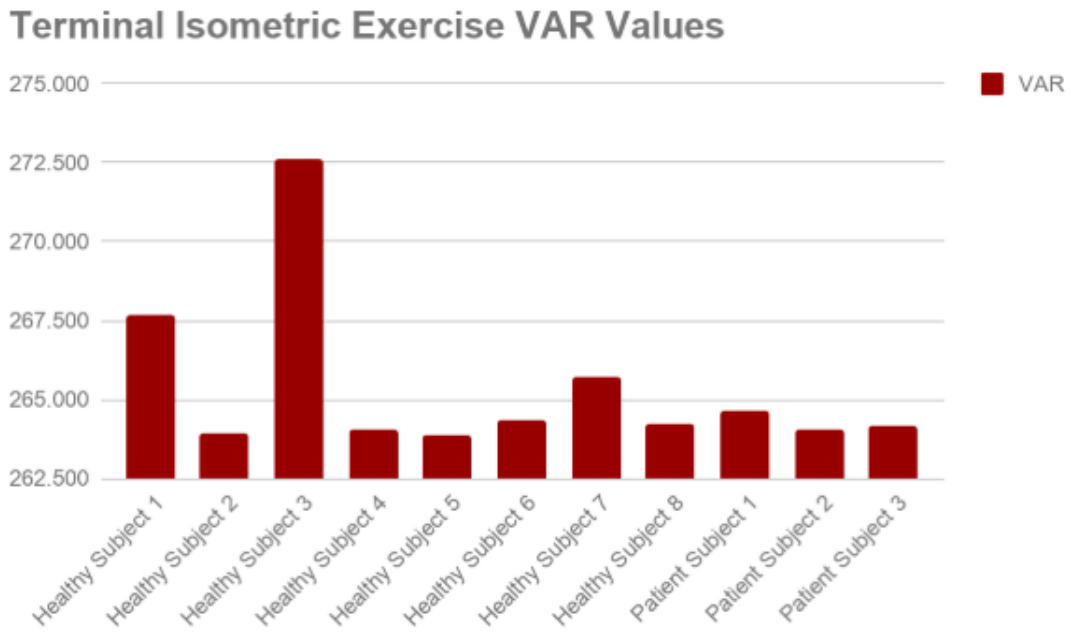

Figure **5.11**: The VAR Analysis Results of Terminal Extension Exercise (Terminal Isometric Exercise) For All Subjects

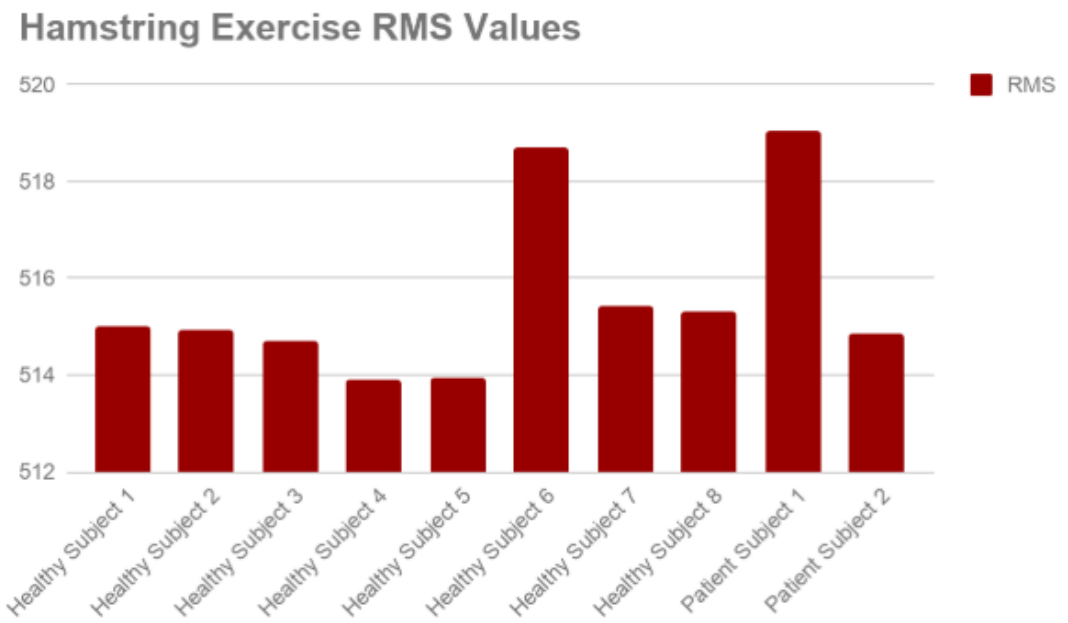

Figure **5.12**: The RMS Analysis Results of Active Knee Flexion Exercise (Hamstring Exercise) For All Subjects

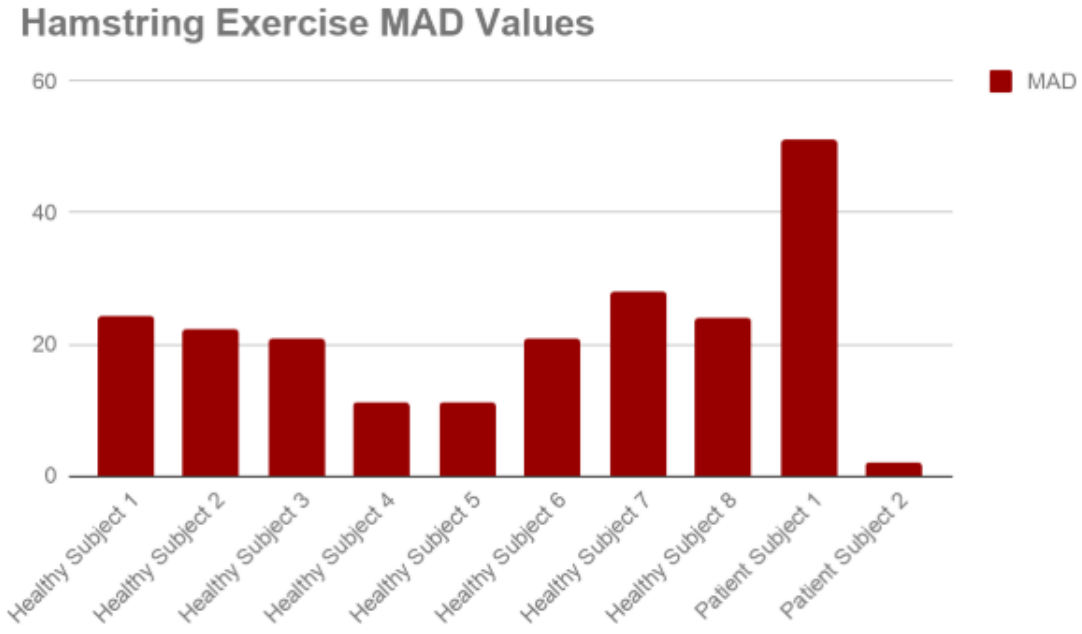

Figure **5.13**: The MAD Analysis Results of Active Knee Flexion Exercise (Hamstring Exercise) For All Subjects

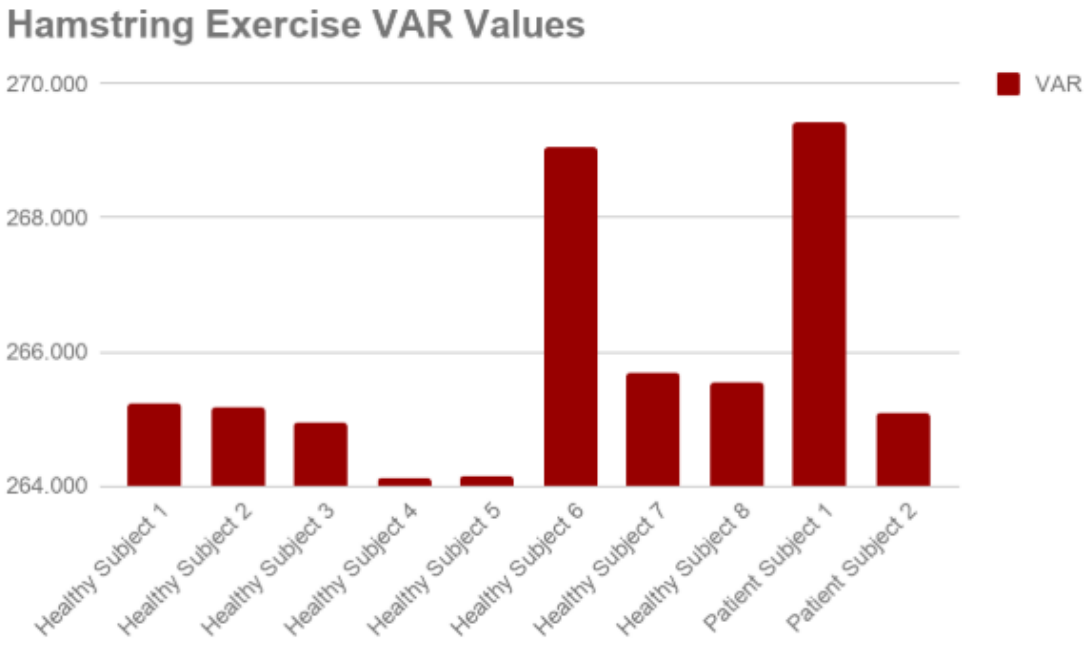

Figure **5.14**: The VAR Analysis Results of Active Knee Flexion Exercise (Hamstring Exercise) For All Subjects

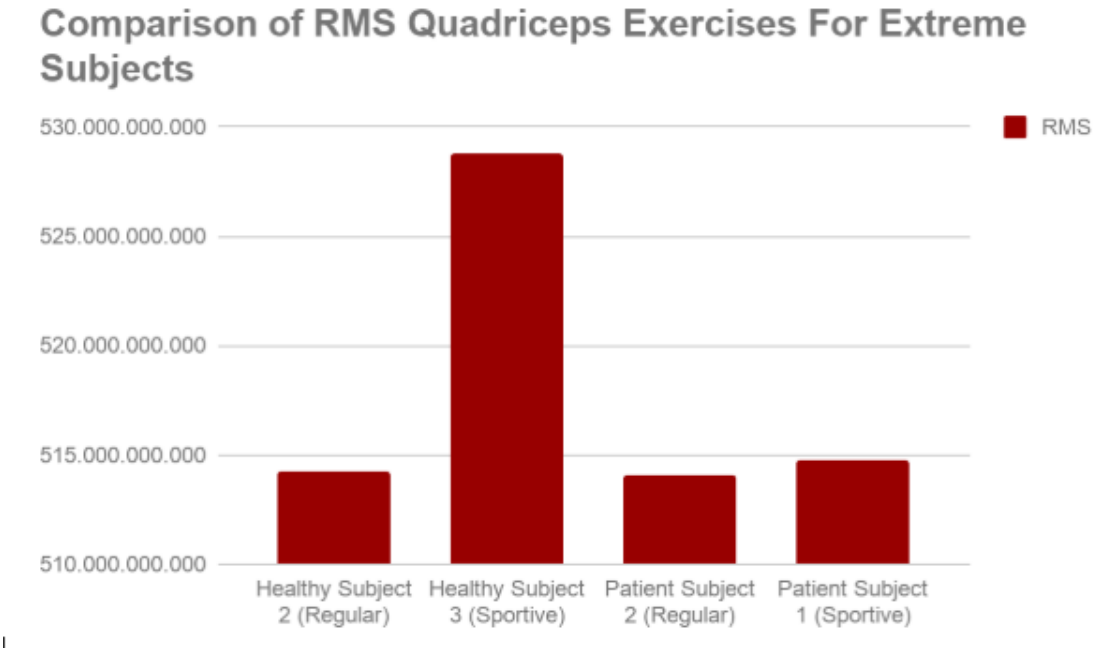

Figure **5.15**: Comparison of RMS Values of Quadriceps Exercises of 4 Extreme Subjects Results

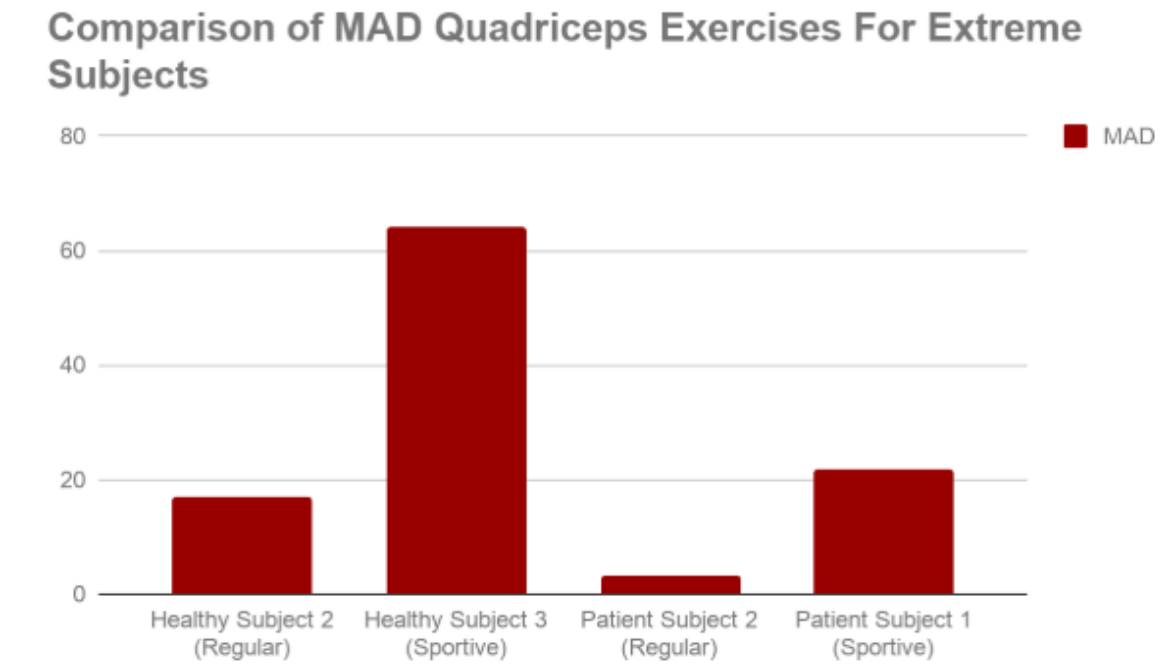

Figure **5.16**: Comparison of MAD Values of Quadriceps Exercises of 4 Extreme Subjects Results

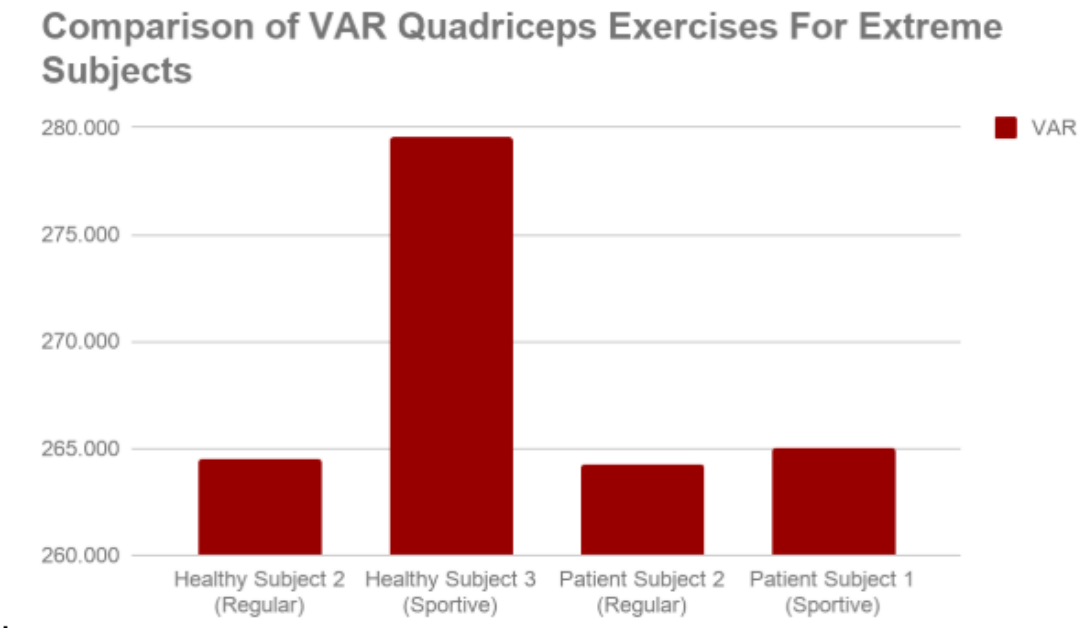

Figure **5.17**: Comparison of VAR Values of Quadriceps Exercises of 4 Extreme Subjects Results

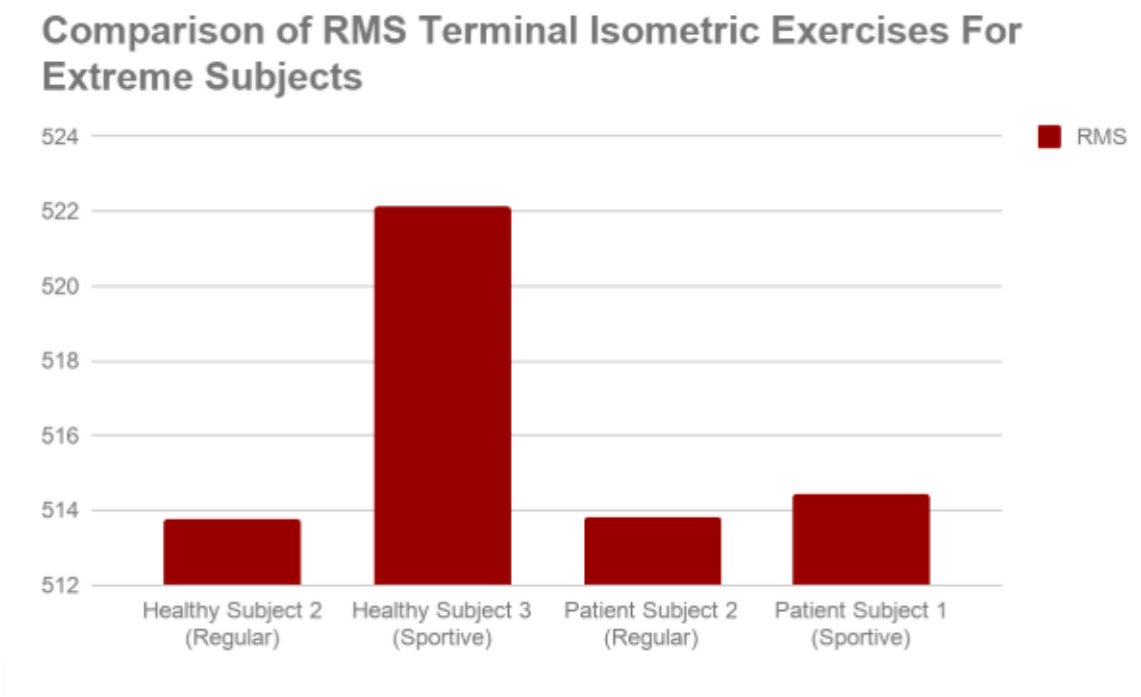

Figure **5.18**: Comparison of RMS Values of Terminal Isometric Exercises of 4 Extreme Subjects Results

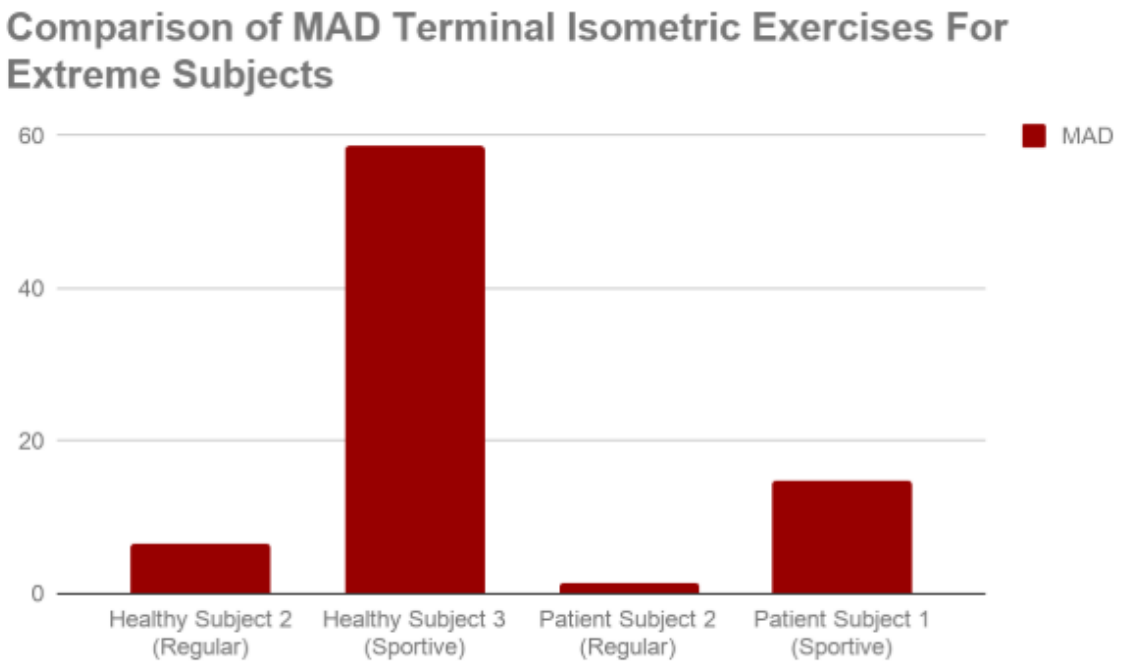

Figure **5.19**: Comparison of MAD Values of Terminal Isometric Exercises of 4 Extreme Subjects Results

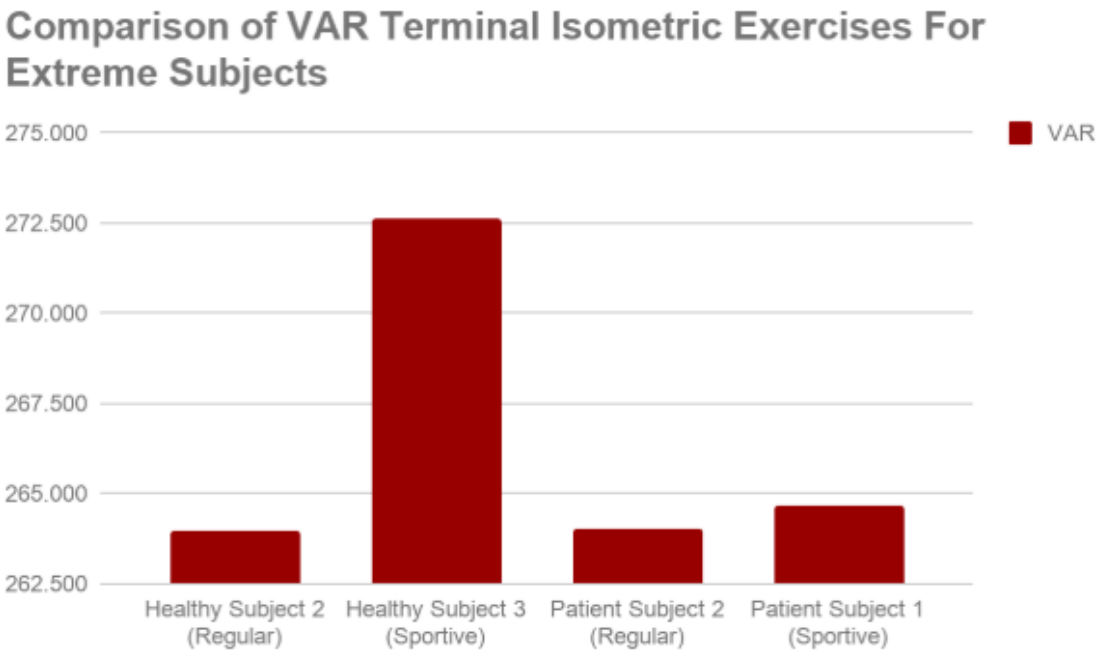

Figure **5.20**: Comparison of VAR Values of Terminal Isometric Exercises of 4 Extreme Subjects Results

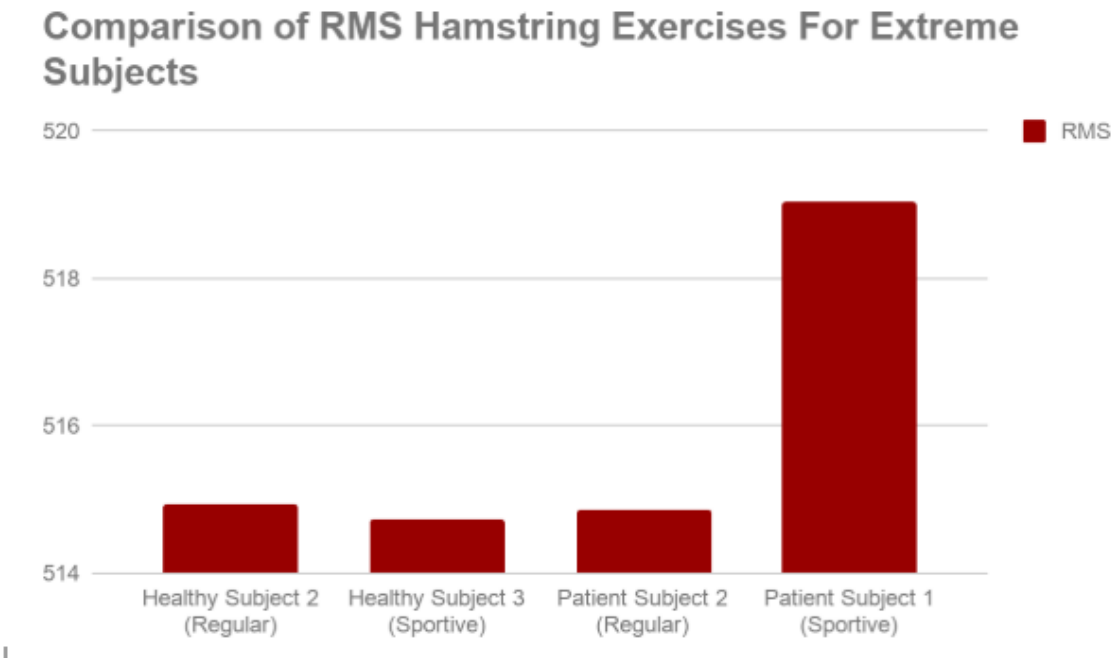

Figure **5.21**: Comparison of RMS Values of Hamstring Exercises of 4 Different Subjects Results

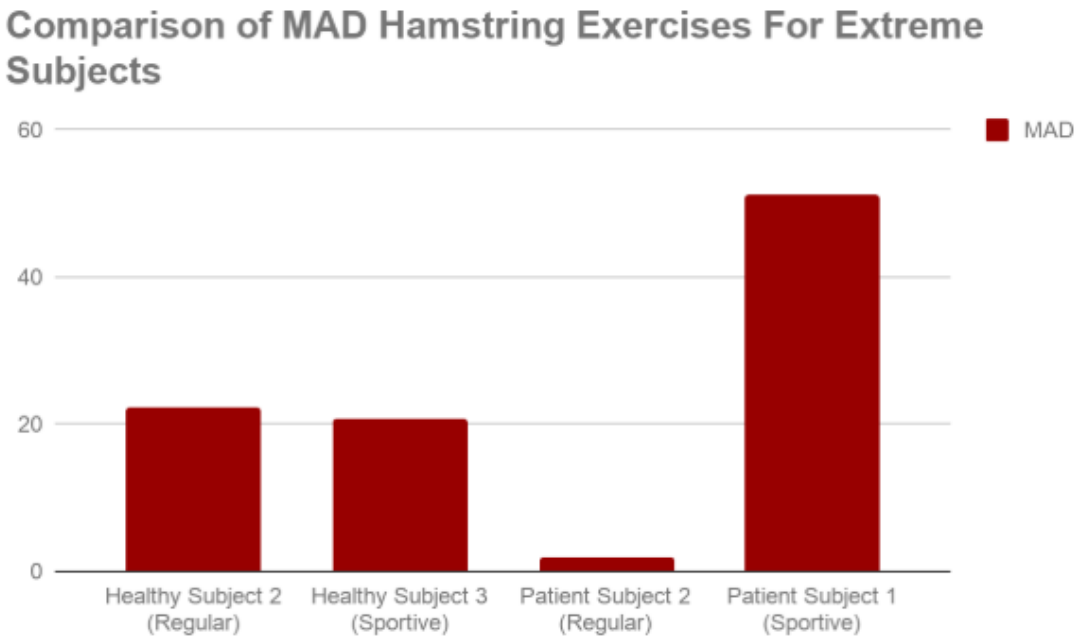

Figure **5.22**: Comparison of MAD Values of Hamstring Exercises of 4 Different Subjects Results

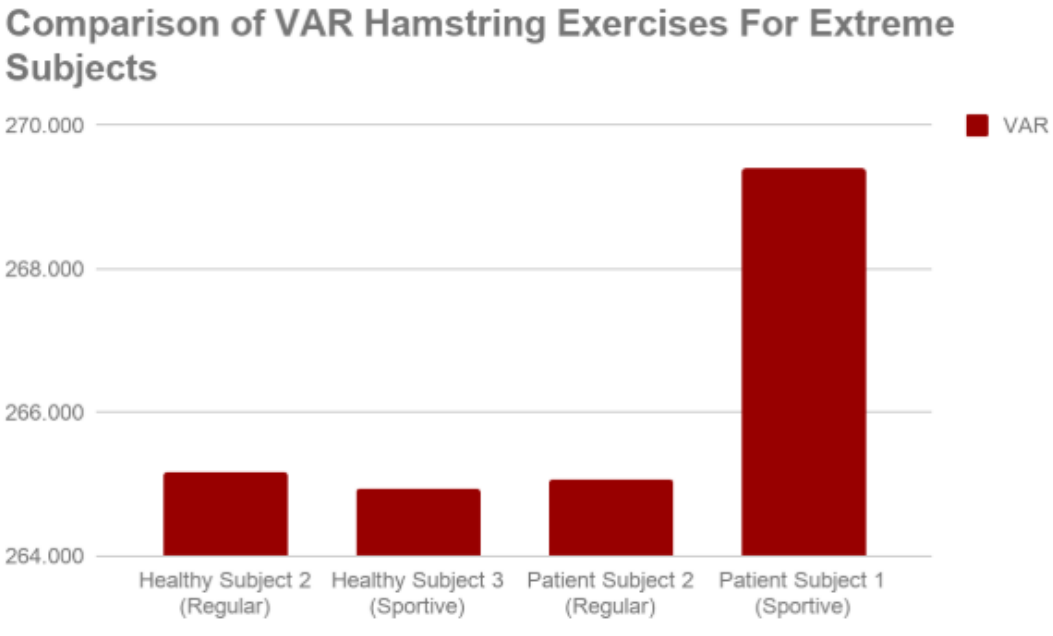

Figure **5.23**: Comparison of VAR Values of Hamstring Exercises of 4 Different Subjects Results

that the patient subject 2 is the weakest link. Hamstring exercise results are different the other two exercises results. Although the patient subject 2 is the weakest link over, healthy subject 3 has not the leading results. One of the reasons for this may be the fatigue of the subject because this exercise was the last exercise. The fact that subjects have different backgrounds may also be the cause of this situation.

5.2 Survey Results

5 physiotherapists and 1 physical therapy rehabilitation specialist medical doctor, they evaluated the feedback module of the system by responding to survey questions. 16 healthy volunteers evaluated the serious game of the system by responding to survey questions.

5.2.1 The Feedback Module Survey Results

Some survey questions were asked to the physiotherapists (6 volunteers) after a demo of the system, for evaluating the feedback module of the system, where physiotherapists can remotely follow-up their patients and access to information about their patients. The survey questions the usefulness of the system, the ease of use of the system, the attitude of the users and the intention of the users. The usefulness of the feedback module results can be seen in Figure **5.24** and the ease of use of the feedback module results can be seen in Figure **5.25**. The attitude of the users results can be seen in Figure **5.26** and the intention of use results can be seen in Figure **5.27**. They were also asked about their recommendations for the feedback module. The answers received will be discussed in the conclusion part as future studies.

5.2.2 The Serious Game Survey Results

After playing the games, the healthy volunteers (16 people) were asked some questions about the games. The survey questions the usefulness of the games, the ease of use of the games, the attitude of the patients/users and the intention of the patients/users. The usefulness of the serious games results can be seen in Figure **5.28** and the ease of use of the serious games results can be seen in Figure **5.29**. The attitude of the users results can be seen in Figure **5.30** and the intention of use results can be seen in Figure

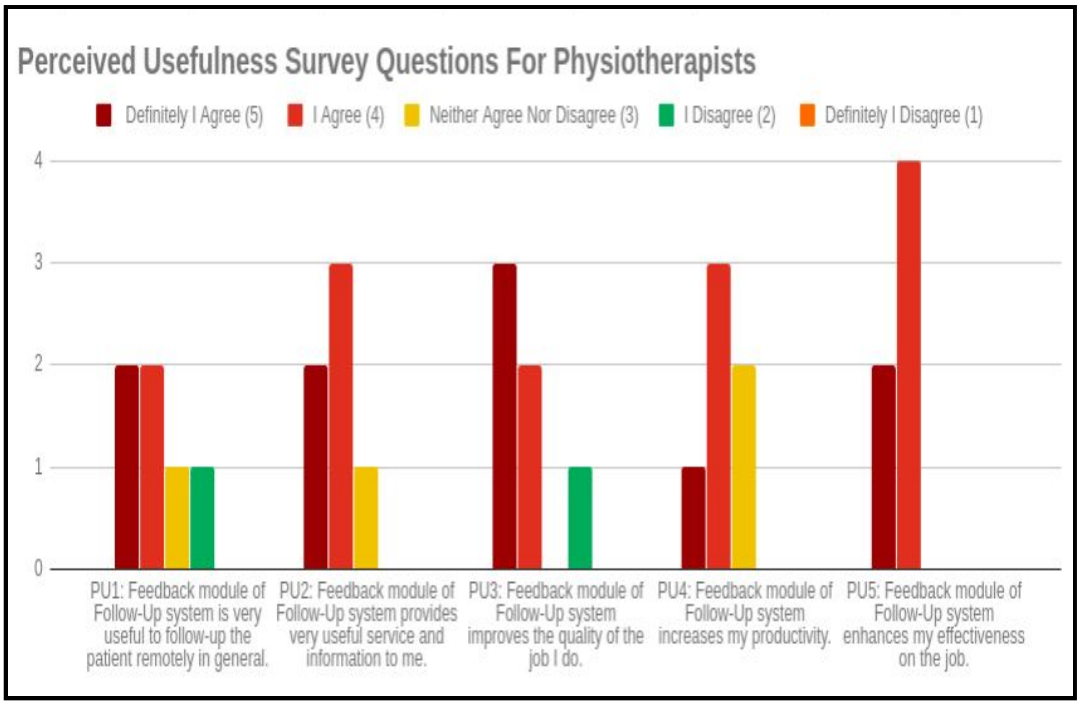

Figure **5.24**: The Usefulness Of The Feedback Module Survey Results

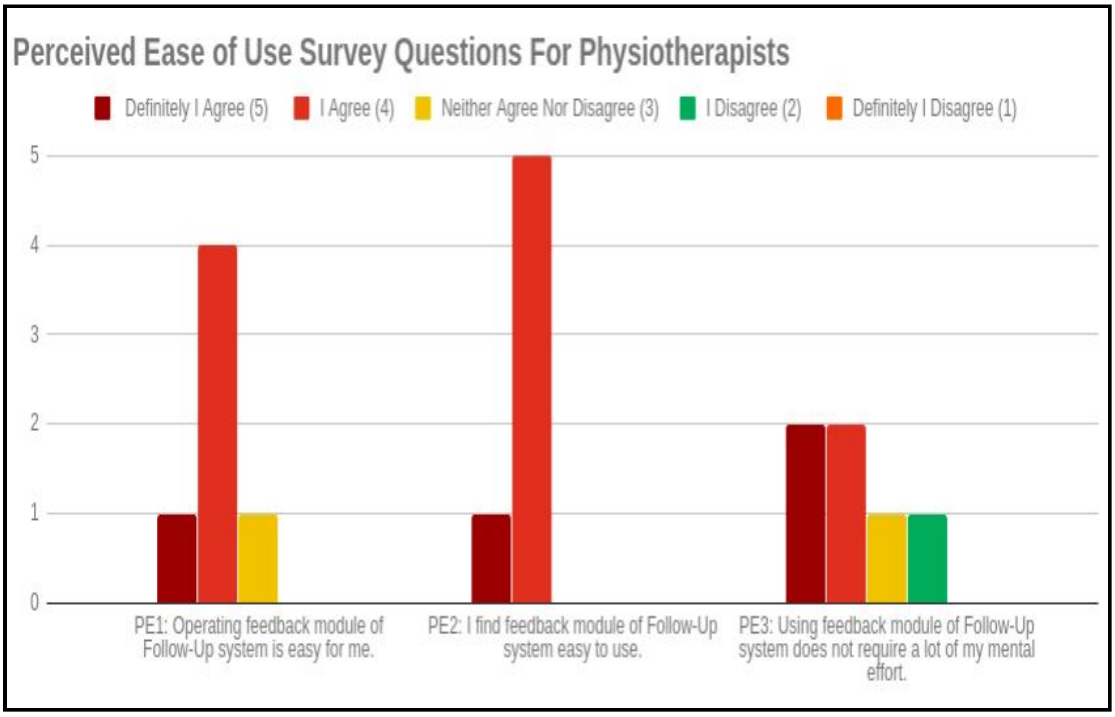

Figure **5.25**: The Ease Of Use Of The Feedback Module Survey Results

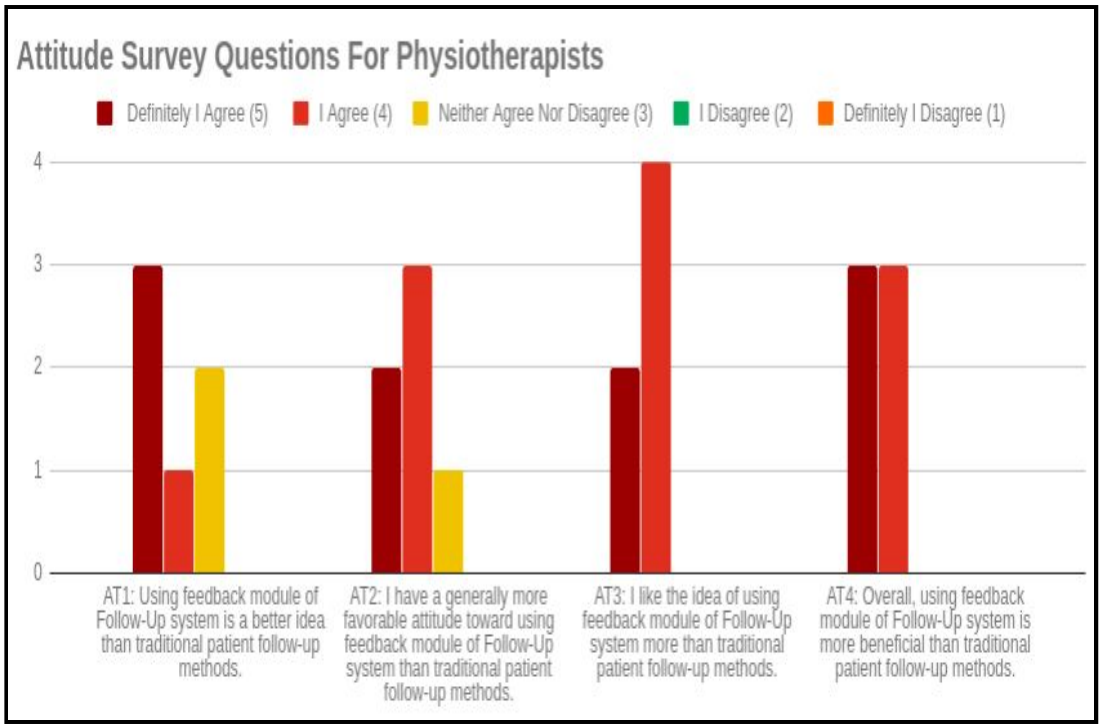

Figure **5.26**: Attitude Of The Users For The Feedback Module Survey Results

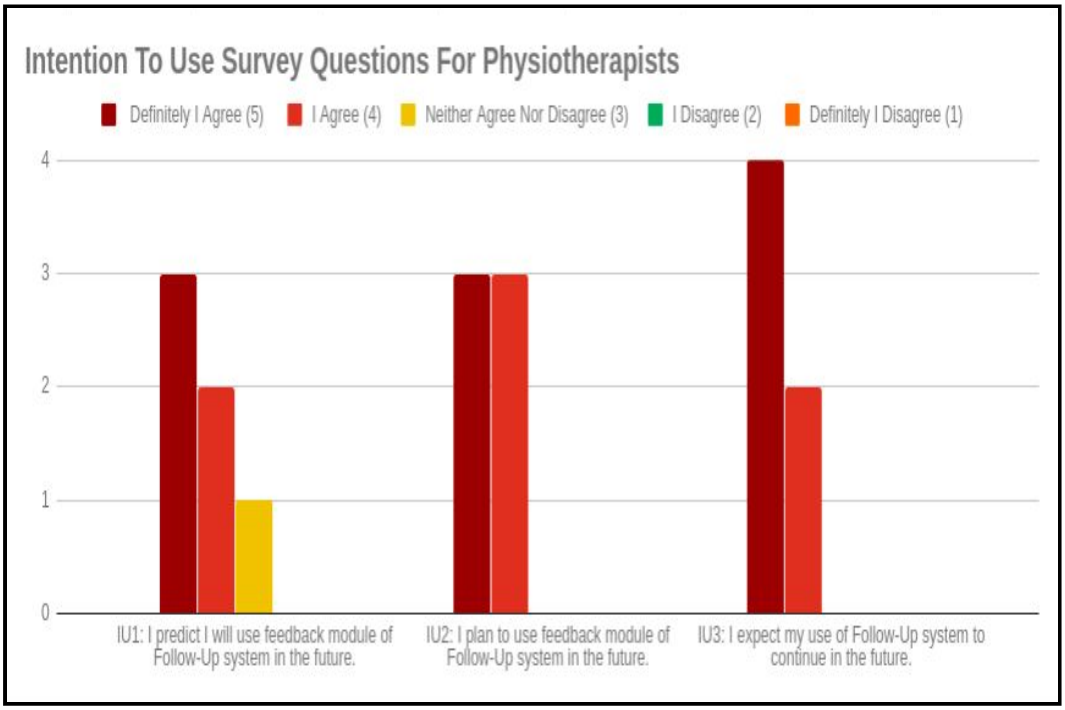

Figure **5.27**: Intention Of Use For The Feedback Module Survey Results

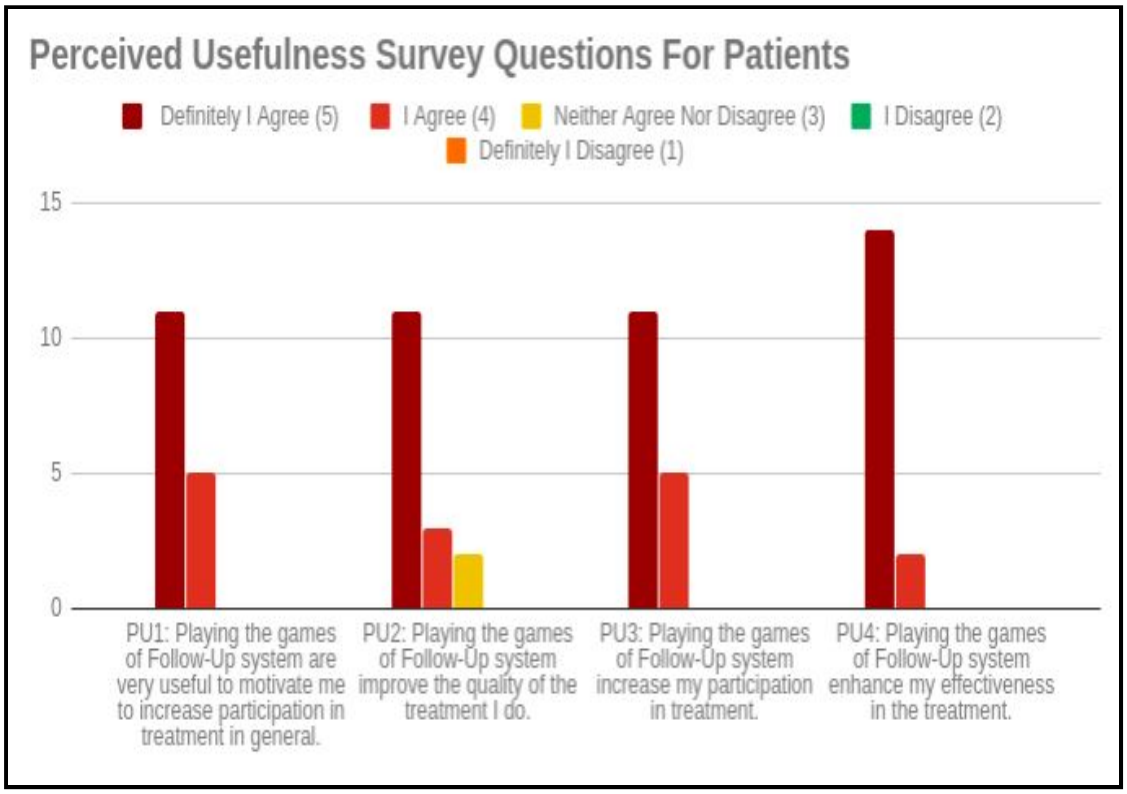

Figure **5.28**: The Usefulness Of The Serious Games Survey Results

5.31. They were also asked about their recommendations for the serious games. The answers received will be discussed in the conclusion part as future studies.

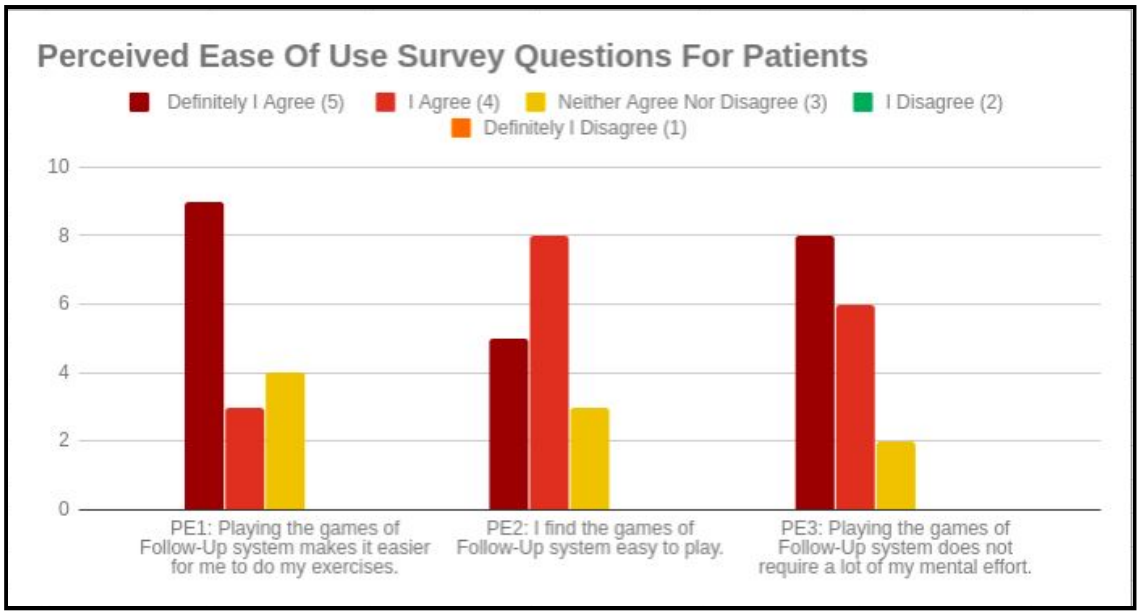

Figure **5.29**: The Ease Of Use Of The Serious Games Survey Results

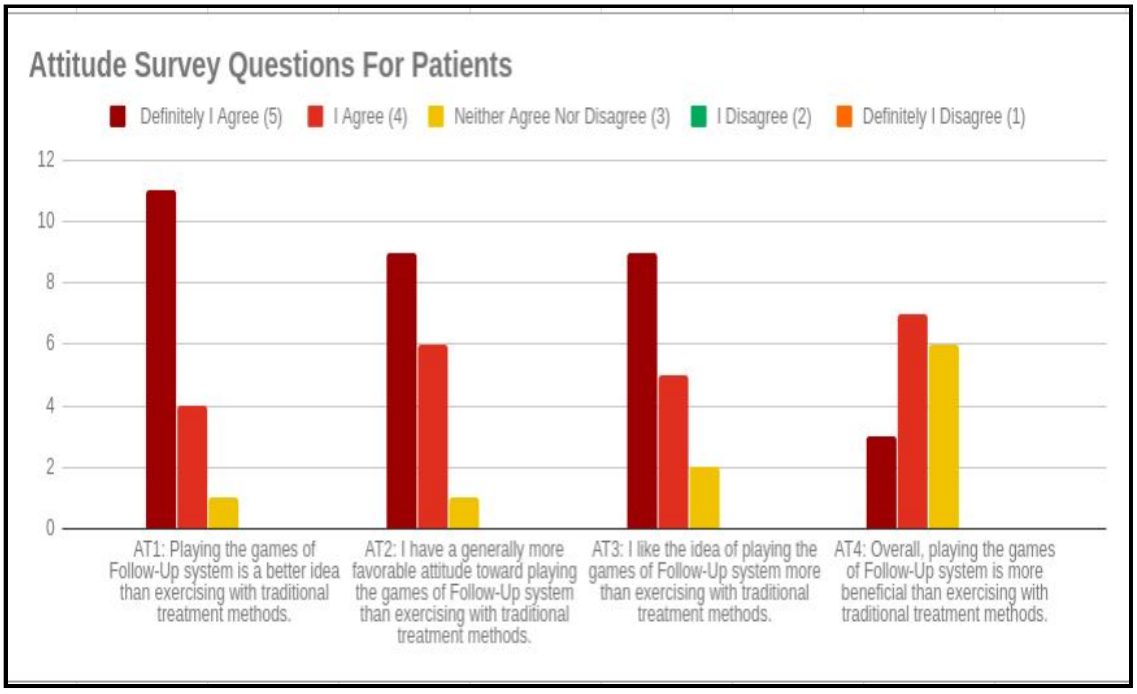

Figure **5.30**: Attitude Of The Users For The Serious Games Survey Results

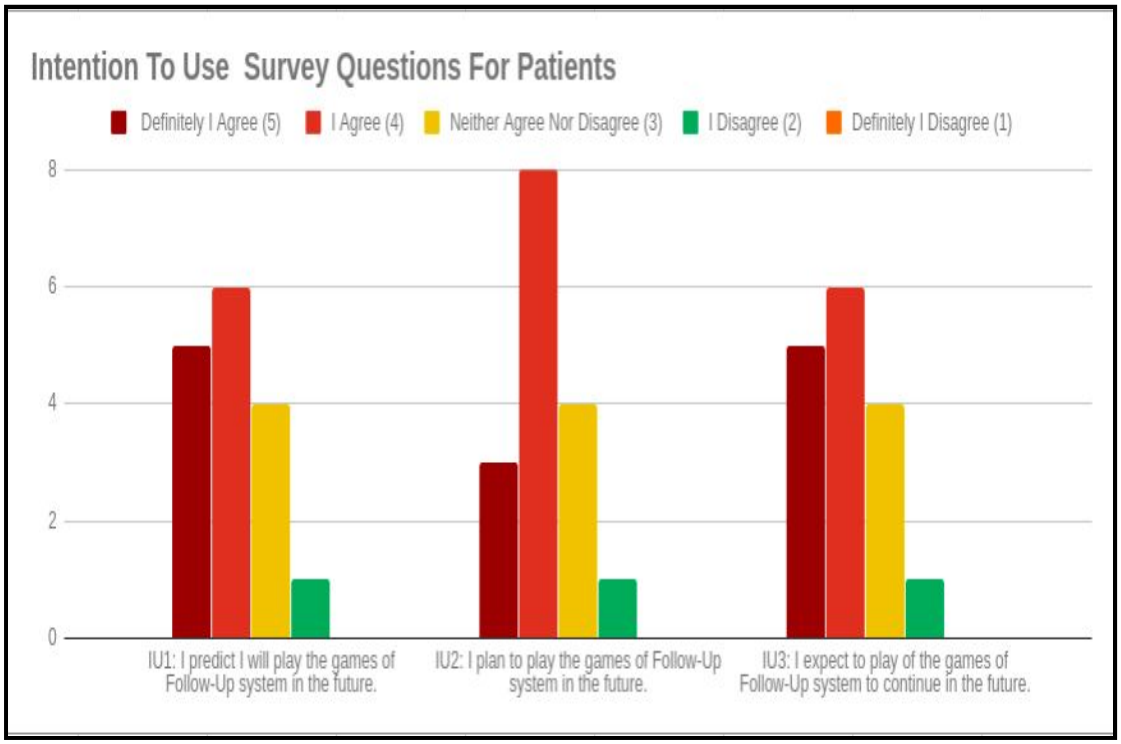

Figure **5.31**: Intention Of Use For The Serious Games Survey Results

6 CONCLUSION & FUTURE STUDIES

It is aimed to create a goal-oriented system for increasing the patient participation in treatment and for providing physiotherapists a tool to remotely follow-up their patients. 3 different and commonly used exercises are selected for strengthening different lower-limb muscles and 3 different games are designed for 3 exercises to increase patients' participation in therapy. Additionally, this system (as web application part) includes a feedback module for physiotherapists, to monitor the progress of the patients remotely. To understand EMG signal and extract useful information from it, sEMG signal data are collected from 8 healthy volunteers and 3 patients. Feature extraction methods applied to EMG signal, provided the feedback to physiotherapist via web based module.Thus, the physiotherapists are enabled to follow-up their patients and they receive information about patient's exercise sessions such as power of EMG, contractile force of muscle and amplitude of EMG. Progress of the patients throughout the sessions also can be reviewed . This complete system can be used in the clinics after scientific tests.

The analysis of the results shows that the data were generally compatible with the subject' backgrounds. These results may enhance the likelihood of usage of the proposed system in clinics as a useful tool both for patients and physiotherapists.

The feedback module and the serious game part of the system were evaluated separately and the questionnaire questions were prepared. The survey results are encouraging. The respondents also made some feedback about the system.

The feedback about the serious game part of the system can be used as a guideline for future work : level module, best scores, game diversity for different exercises/muscles, mobile application, virtual reality application, patient guidance in the game, demonstration video and adults/pediatrics difference should be investigated.

The level module can be summarized as follows : As the patient progresses, the level of the game may be difficult, thus, patient can use this system until the end of treatment. This also introduces a system mechanics that can be customized to the individual. The best scores can be summarized as follows : The patient progresses by breaking his/her own record as he/she progressesand this is a motivating factor. The game diversity for different exercises/muscles can be summarized as follows : The games can be diversified according to other exercises. other muscle groups can be worked. The

mobile application can be summarized as follows : If this system turns into a mobile application, the access of patients will increase and so more patients will benefit. The virtual reality application can be summarized as follows : If the system is redesigned as a virtual reality application, the attractiveness will increase and thus the number of patients using the system will be increased. The patient guidance in the games and demonstration video of the games can be summarized as follows : They will improve the clarity of games and help to the patients. The adults/pediatrics difference can be summarized as follows : Different games can be prepared according to the age groups of the patients. For example, more colorful, animated games can be designed for children.

The feedback about the feedback module of the system can be listed as follows in the future : limb angle measurement (range)(using with Kinect), warning system for physiotherapists, alarm system for patients and interpretation according to the obtained data (decision support system).

The limb angle measurement (range)(using with Kinect) can be summarized as follows : In physiotherapy and rehabilitation, as well as the work of the muscles, it is important to make the movement functionally correct. Therefore, the system should be supported by a device that can also measure the angle of the limb (like as Kinect). The warning system for physiotherapists can be summarized as follows : As part of the patient follow-up, the physiotherapist may receive a notification when the patient does not exercise. The alarm system for patients can be summarized as follows : If the patient forgets to exercise, the patient may receive a notification also. The interpretation according to the obtained data can be summarized as follows : The system can interpret the development of the patients according to the their data and it can help to the physiotherapists (like as a ecision support system).

This system is open to development according to the needs of physiotherapists and patients. According to the needs of patients and physiotherapists, it can be constantly renewed and changed. Thus, it does not deviate from the two main objectives that it originally intended : increase patient motivation to participate in treatment and provide a feedback module to physiotherapists.

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APPENDIX A İSTINYE UNIVERSITY CLINICAL RESEARCH ETHICS COMMITTEE APPROVAL LETTER PAGES

İSÜ İSTİNYE ÜNİVERSİTESİ İSTANBUL

T.C.
İSTİNYE ÜNİVERSİTESİ
KLİNİK ARAŞTIRMALAR ETİK KURULU
(2017-KAEK-120)

İSÜ İSTİNYE ÜNİVERSİTESİ İSTANBUL

Sayı : (2017-KAEK-120) /35 **Tarih : 09.05.2018**
Konu : Ar. Gör. Tuğba GÜNAYDIN Hk.

Sayın Ar. Gör. Tuğba GÜNAYDIN

İlgi :İSÜ Sağlık Bilimleri Fakültesi Fizyoterapi ve Rehabilitasyon Bölüm Başkanlığı 13/04/2018 ve tarihli yazısı

Sorumlu araştırıcılığını üstlendiğiniz 13 dosya numaralı "Fizyoterapi ve Rehabilitasyonda Alt Ekstremite Kas Kuvvetlendirme Egzersizleri İçin Yüzey Elektromiyografisi Bazlı Ciddi Bilgisayar Oyunu" başlıklı Araştırma başvurunuz kurulumuzun 04/05/2018 gün ve 2018/07 nolu toplantısında görüşülerek etik yönden uygun bulunmuş olup, tutanaklar ekte sunulmuştur.

Bilgilerinizi rica ederim.

Prof. Dr. Yusuf SARIOĞLU
İstinye Üniversitesi
Klinik Araştırmalar Etik Kurul Başkanı

Ek: İstinye Üniversitesi Klinik Araştırmaları Etik Kurulu Karar Formu

İSTİNYE ÜNİVERSİTESİ KLİNİK ARAŞTIRMALARI ETİK KURULU KARAR FORMU(2017-KAEK-120)

ARAŞTIRMANIN AÇIK ADI	**"Fizyoterapi ve Rehabilitasyonda Alt Ekstremite Kas Kuvvetlendirme Egzersizleri İçin Yüzey Elektromiyografisi Bazlı Ciddi Bilgisayar Oyunu"**
VARSA ARAŞTIRMANIN PROTOKOL KODU	---

ETİK KURUL BİLGİLERİ	ETİK KURULUN ADI	**İSTİNYE ÜNİVERSİTESİ KLİNİK ARAŞTIRMALARI ETİK KURULU (2017-KAEK-120)**
	AÇIK ADRESİ:	Maltepe Mah., Edirne Çırpıcı Yolu, No.9 Zeytinburnu, İstanbul
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BAŞVURU BİLGİLERİ	KOORDİNATÖR/SORUMLU ARAŞTIRMACI UNVANI/ADI/SOYADI	**Ar. Gör. Tuğba GÜNAYDIN**			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ UZMANLIK ALANI	**Bilgisayar Mühendisi-İnsan Bilgisayar Etkileşimi**			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ BULUNDUĞU MERKEZ	**İstinye Üniversitesi Yazılım Mühendisliği**			
	VARSA İDARİ SORUMLU UNVANI/ADI/SOYADI	**Yok**			
	DESTEKLEYİCİ	**Yok**			
	PROJE YÜRÜTÜCÜSÜ UNVANI/ADI/SOYADI (TÜBİTAK vb. gibi kaynaklardan destek alanlar için)	**Yok**			
	DESTEKLEYİCİNİN YASAL TEMSİLCİSİ	**Yok**			
	ARAŞTIRMANIN FAZI VE TÜRÜ	FAZ 1	☐		
		FAZ 2	☐		
		FAZ 3	☐		
		FAZ 4	☐		
		Gözlemsel İlaç Çalışması	☐		
		Tıbbi cihaz Klinik Araştırması	☐		
		İn Vitro Tıbbi Tanı Cihazları İle Yapılan Performans Değerlendirme Çalışmaları	☐		
		İlaç Dışı Klinik Araştırma	☐		
		Diğer ise belirtiniz	■ Biyomedical/Biyo-Feedback Çalışması		
	ARAŞTIRMAYA KATILAN MERKEZLER	TEK MERKEZ ■	ÇOK MERKEZLİ ☐	ULUSAL ■	ULUSLARARASI ☐

Etik Kurul Başkanının
Unvanı/Adı/Soyadı: **Prof. Dr. Yusuf SARIOĞLU**
İmza:

APPENDIX B INFORMED CONSENT FORM PAGES

BİLGİLENDİRİLMİŞ GÖNÜLLÜ OLUR FORMU

Sayın ..... (gönüllü adayı / gönüllü adayı yasal temsilcisi);

Sizi İstinye Üniversitesi Fizyoterapi ve Rehabilitasyon Laboratuvarı'nda yürütülen *"Fizyoterapi ve Rehabilitasyonda Alt Ekstremite Kas Kuvvetlendirme Egzersizleri için Yüzey Elektromiyografisi Bazlı Ciddi Bilgisayar Oyunu"* başlıklı araştırmaya davet ediyoruz. Bu araştırmaya katılıp katılmama kararını vermeden önce, araştırmanın ne amaçla ve nasıl yapılacağını, bu araştırmanın gönüllü katılımcılara getireceği olası faydaları, riskleri ve rahatsızlıklarını bilmeniz ve kararınızı bu bilgilendirme çerçevesinde özgürce vermeniz gerekmektedir. Bu nedenle bu formun okunup anlaşılması büyük önem taşımaktadır. Bu form araştırma sorumlusu olarak bizler tarafından size sözel olarak aktarılan bilgilendirmenin yazılı şeklini içermektedir. Formu imzalamadan önce size sözel olarak da anlatılan aşağıdaki bilgileri birkez de dikkatlice okumak için zaman ayırınız. İsterseniz bu bilgileri aileniz, yakınlarınız ve/veya doktorunuzla tartışınız. Eğer anlayamadığınız ve sizin için açık olmayan şeyler varsa, ya da daha fazla bilgi isterseniz bize sorunuz. Katılmayı kabul ettiğiniz takdirde, tarafınız ve bilgilendirme esnasında yanınızda olan tanık kişi tarafından imzalanan bu formun bir kopyası saklamanız için size verilecektir.

Araştırmaya katılmak tamamen gönüllülük esasına dayanmaktadır. Çalışmaya katılmama veya katıldıktan sonra herhangi bir anda çalışmadan çıkma hakkında sahipsiniz. Her iki durumda da hiçbir yaptırıma ve hak kaybına maruz kalmayacağınızı bildirmek isteriz.

Araştırma Sorumlusu
(Adı-Soyadı-Ünvanı-imza)
Bilgisayar Mühendisi (Araş. Gör.) Tuğba Günaydın

Bu "Bilgilendirilmiş Gönüllü Olur Formu" 2 bölümden oluşmaktadır;

1) **BİLGİLENDİRME**
2) **RIZA**

BÖLÜM 1: BİLGİLENDİRME

- **ARAŞTIRMANIN AMACI NEDİR?**

Gönüllü olarak katılmanızı teklif ettiğimiz çalışma bir araştırma projesidir. Bu araştırma projesi:

Alt ekstremitedeki kasların güçsüzleşmesi durumlarında bazı hastalara fizyoterapi ve rehabilitasyon tavsiye edilmektedir. Bu çalışmanın konusu uyluk ön ve arka bölgesindeki kasların kuvvetlendirilmesi egzersizleridir. Bu egzersizler yapılırken hastanın motivasyonunun artırılması ve fizyoterapistin rahat bir şekilde hasta kontrolünü sağlaması için farklı yöntemler kullanılmaktadır. Bu yöntemlerden biri de ciddi oyundur. Ciddi oyun, tedavi ve/veya eğitim amaçlı kullanılan bilgisayar oyunlarının genel adıdır. Bu çalışmada,

yüzeyel elektrotlar kullanılarak yukarıda bahsedilen kaslarınızda hareket sonucunda oluşan elektriksel dalgalar ölçülerek egzersiz esnasında kaslarınızın kuvveti değerlendirilecektir. Elde edilen veriler ile oyundaki karakteriniz hareket edecek ve tedaviniz bu şekilde devam edecektir. Tedaviye katılımınız ölçülecek ve elde edilen verilerle (EMG) ekrandaki karakterin hareket etmesi sağlanacaktır.

- **ARAŞTIRMAYA DAİR ARAŞTIRMACI VE KATILIMCI HAKKINDA BİLGİLER**

Araştırma İstinye Üniversitesi Fizyoterapi ve Rehabilitasyon Laboratuvarı'nda yapılacaktır. Çalışma, sorumlu araştırmacı Bilgisayar Mühendisi (Araş. Gör.) Tuğba Günaydın ve yardımcı araştırmacı Fizyoterapist (Araş. Gör.) Betül Bırık tarafından yürütülmektedir. Tuğba Günaydın 2015 yılında Galatasaray Üniversitesi Bilgisayar Mühendisliği Programı'ndan mezun olmuştur. Daha önce ALS hastaları için iletişim ara yüzleri geliştiren bir AR-GE firması bünyesinde proje süresi boyunca (1 yıl) çalışmıştır. Ardından İstinye Üniversitesi Yazılım Mühendisliği Programı'nda Araştırma Görevlisi olarak çalışma hayatına ve Galatasaray Üniversitesi Bilgisayar Mühendisliği Yüksek Lisans Programı'nda da eğitim hayatına devam etmektedir. Betül Bırık ise lisans eğitimini 2016 yılında Dokuz Eylül Üniversitesi Fizyoterapi ve Rehabilitasyon Bölümü'nde tamamlamıştır. Aynı yıl, Bezmiâlem Vakıf Üniversitesi'nde Fizyoterapi ve Rehabilitasyon Yüksek Lisans Programı'na başlamıştır. 2016 Ekim ayından beri İstinye Üniversitesi Fizyoterapi ve Rehabilitasyon Bölümünde Araştırma Görevlisi olarak çalışma hayatına devam etmektedir.

Çalışmaya 128 gönüllünün katılması amaçlanmıştır. Bu çalışmada kullanılmak üzere demografik bilgileriniz kaydedilecek olup, ilgili kaslarınızın kuvvetini ölçen manuel kas testi yapılacak ardından uyluk ön ve arka bölgesini kuvvetlendiren egzersizler esnasında bacağınızın ilgili bölgelerine yerleştirilecek olan yüzeyel elektrotlarla veri toplanacaktır. Herhangi bir invaziv (girişimsel) bir işlem gerçekleştirilmeyecektir. Tüm değerlendirme ve tedavi esnasındaki veri toplama işlemleri ortalama 10 dakika sürecektir.

- **ARAŞTIRMAYA KATILMANIZI NEDEN TEKLİF EDİYORUZ?**

Bu çalışmaya dahil olma kriterleri şunlardır: Bilgisayar kullanmayı bilme (en basit seviye), alt ekstremite quadriceps ve hamstring kasları (her ikisi de üst bacak kas gruplarıdır) kuvvetlendirme için fizyoterapi ve rehabilitasyon tavsiye edilmiş olma, çalışmaya katılmak için gönül rızası olma. Bu kriterlerin hepsini birden sağladığınız için bu çalışmaya katılmanızı teklif ediyoruz. Bu çalışmanın çıktılarına göre cevap aradığımız sorular şunlardır: Fizyoterapi ve rehabilitasyon süreçleri bu çalışma sayesinde fizyoterapistler tarafından daha rahat takip edilebilecek mi? Bu çalışma hastalara daha etkin bir tedavi sunulmasını sağlayacak mı? Sorduğumuz sorular çalışma sonunda olumlu cevaplanırsa bu sistem sayesinde fizyoterapi ve rehabilitasyon tedavileriniz daha etkin bir şekilde gerçekleştirilebilecektir. Ayrıca bu çalışmaya katıldığınızda, bilime yeni bilgiler kazandırılmasına katkıda bulunmuş da olacaksınız. Çalışmaya katılmayı kabul etmez veya herhangi bir zamanda çalışmadan ayrılmayı isterseniz bu durumun hiçbir yaptırımı, tedavi sürecine olumsuz etkisi olmayacaktır.

- **ARAŞTIRMA KAPSAMINDA NASIL BİR UYGULAMA YAPILACAKTIR? YÖNTEM VE İŞLEMLER NELERDİR?**

Ekrandaki oyun karakteriyle birlikte sizlere verilen egzersizleri yapacaksınız ve toplamda 10 dakika sürecektir. Herhangi bir komplikasyon yoktur. Egzersiz yapılacağı için tedaviye daha rahat giysilerle (eşofman gibi) gelmeniz daha uygun olacaktır.

- **ARAŞTIRMANIN BİLİME VE SİZE OLASI FAYDALARI NELERDİR?**

Bu çalışmanın çıktılarına göre sorduğumuz sorular olumlu cevaplanırsa fizyoterapi ve rehabilitasyon süreçleri fizyoterapistler tarafından daha rahat takip edilebilecek ve hastalara daha etkin bir tedavi sunulacaktır. Ayrıca bu çalışmaya katıldığınızda, bilime yeni bilgiler kazandırılmasına katkıda bulunmuş da olacaksınız.

- **ARAŞTIRMANIN SİZE GETİREBİLECEĞİ EK RİSK VE RAHATSIZLIKLAR NELERDİR?**

Herhangi bir risk yoktur. Size doktorunuz tarafından tavsiye edilen fizyoterapi ve rehabilitasyon tedavisi aynı şekilde uygulanacaktır. Yapılan çalışma yalnızca tedavinin etkinliğini izleyebilme amacıyla gerçekleştirilmektedir. Bu sebeple bu çalışma sebebiyle ek bir risk altına girmezsiniz.

- **ARAŞTIRMAYA KATILMA / AYRILMA KONUSUNDA HAKLARINIZ VE ARAŞTIRMACININ HAKLARINIZI KORUMA GÜVENCESİ**

Bu araştırmada yer almak tamamen sizin isteğinize bağlıdır. Araştırmada yer almayı reddedebilirsiniz ya da başladıktan sonra herhangi bir zamanda bırakabilirsiniz. Ayrıca sorumlu araştırıcı gerek duyarsa sizi çalışma dışı bırakabilir. Çalışmaya katılmama, çalışmadan çıkma veya çıkarılma durumlarında herhangi bir ceza ya da yararınıza olan hakların kaybı kesinlikle söz konusu olmayacaktır. Araştırma konusu ile ilgili araştırmaya devam etme isteğinizi etkileyebilecek yeni bilgiler elde edilmesi durumunda siz ya da yasal temsilciniz bilgilendirilecektir.

Araştırmanın sonuçları bilimsel ve eğitim amaçları ile kullanılacaktır. Sizden elde edilen tüm bilgiler tamamen araştırma amacı ile kullanılacak, gizli tutulacak, araştırma yayınlandığında da varsa kimlik bilgilerinizin gizliliği korunacaktır. Araştırma tamamlanmadan çekilme hakkınızı kullanmanız ya da çıkarılmanız halinde anonimleşmiş bilgiler hariç sizle ilgili veriler kullanılmayacaktır ve sizinle bu çalışmanın sonuçları ile alakalı herhangi bir şekilde iletişime geçilmeyecektir.

- **ARAŞTIRMA MASRAFLARI NASIL SAĞLANACAKTIR?**

Araştırma kapsamında size uygulanacak hiçbir işlem için tarafınızdan ya da bağlı olduğunuz sosyal güvenlik kurumunda ücret alınmayacaktır.

- **İLETİŞİM KURULACAK KİŞİ(LER)**

Sorumlu araştırmacı Bilgisayar Mühendisi (Araş. Gör.) Tuğba Günaydın Tel: 0551 438 4259
Yardımcı araştırmacı Fizyoterapist (Araş. Gör.) Betül Bırık Tel: 0532 787 9969

- **ŞİKAYET BAŞVURULARI**

Çalışma hususunda bir şikayetiniz olması halinde İstinye Üniversitesi Klinik Araştırmalar Etik Kurul Sekreteryası ile iletişim sağlayabilirsiniz. Şikayetleriniz gizlilikle değerlendirilecek, araştırılacak ve sonuç hakkında tarafınıza bilgi verilecektir.

- **YUKARIDA BELİRTİLEN HUSUSLAR DIŞINDA SORULARINIZ VAR İSE, BU BÖLÜME EKLENEREK CEVAPLANDIRILACAKTIR.**

☐ **Gönüllünün sorduğu ek sorular ve cevapları**

☐ **Ek bir soru bulunmamaktadır.**

BÖLÜM 2: RIZA / ONAY / ONAM

Yukarıda konusu ve amacı belirtilen araştırmaya ilişkin bilgilendirme bölümünü okudum ve aşağıda imzası olan ilgili tarafından önce sözlü sonra yazılı olarak bilgilendirildim. Katılmam istenen çalışmanın kapsamını ve amacını, gönüllü olarak üzerime düşen sorumlulukları tamamen anladım. **Çalışma hakkında soru sorma ve tartışma imkanı buldum ve tatmin edici yanıtlar aldım. Bana, çalışmanın muhtemel riskleri ve faydaları sözlü olarak da anlatıldı.** Araştırmaya gönüllü olarak katıldığımı, istediğim zaman gerekçeli veya gerekçesiz olarak araştırmadan ayrılabileceğimi ve kendi isteğime bakılmaksızın araştırmacı tarafından araştırma dışı bırakılabileceğimi ve araştırmadan ayrıldığım zaman mevcut tedavimin olumsuz yönde etkilenmeyeceğini biliyorum.

Bu koşullarda;

1) Söz konusu Klinik Araştırmaya hiçbir baskı ve zorlama olmaksızın kendi rızamla katılmayı (çocuğumun/vasimin bu çalışmaya katılmasını) kabul ediyorum.

2) Gerek duyulursa kişisel bilgilerime mevzuatta belirtilen kişi/kurum kuruluşların erişebilmesine,

3) Çalışmada elde edilen bigilerin (*kimlik bilgilerim gizli kalmak koşulu ile*) yayın için kullanılma, arşivleme ve eğer gerek duyulursa bilimsel katkı amacı ile ülkemiz dışına aktarılmasına olur veriyorum.

Ek başkaca bir açıklamaya gerek duymadan, hiçbir baskı altında kalmadan ve bilinçli olarak bu klinik araştırmaya katılmayı onaylıyorum.

Gönüllünün (Kendi el yazısı ile)
Adı-Soyadı:
İmzası:
Adresi:
(varsa Telefon No, Faks No):
Tarih (gün/ay/yıl): …./…./….

Velayet veya Vesayet Altında Bulunanlar İçin
Veli veya Vasisinin (kendi el yazısı ile)[1]
Adı Soyadı:
İmzası:
Adresi:
Varsa Telefon No, Faks No:
Tarih (gün/ay/yıl): …/…./….

Gönüllünün Dil / İletişim Problemi var ise;

Gönüllüye …….. tarafından yapılan tüm açıklamaları tercüme ettim. Gönüllüye toplam 5 sayfadan, bilgilendirme ve rıza bölümlerinden oluşan bu formun tüm sayfalarını okuyarak tercüme ettim. Tercüme ettğim bilgiler gönüllü tarafından anlaşılmış ve uygun bulunmuştur.

Tercüme Yapanın
Adı –Soyadı (el yazısı ile)
İmza
Tarih / Saat

Varsa Onay Alma İşlemine Başından Sonuna Kadar Tanıklık Eden Kişi
Adı-Soyadı:
İmzası:
Görevi:
Tarih (gün/ay/yıl):…../…../…..

Yukarıda ismi yazılı gönüllüye / yasal temsilcisine tarafımdan araştırmanın amacı, içeriği, yöntemi, fayda ve riskleri, gönüllüye ait haklar konusunda açıklamalar yapılmıştır. Hastanın soruları yanıtlanmıştır. Ayrıca gönüllünün / yasal temsilcisinin işbu formu ayrıntılı inceleyerek imzalaması sağlanmıştır.

Açıklamaları Yapan Kişinin
Adı-Soyadı:
İmzası:
Tarih (gün/ay/yıl):…/…./…..

Toplam 5 sayfadan oluşan işbu Bilgilendirilmiş Gönüllü Olur Formu 2 nüsha olarak hazırlanmış olup, bir nüshası hastaya/ hasta yakınına teslim edilmiştir.

[1] 18 yaş altındaki gönüllüler, velayet ve vesayet altındaki hastalar için imza süreci Helsinki Bildirgesi, Medeni Kanun, Hasta Hakları Yönetmeliği, Klinik Araştırmalar Kılavuzuna ve Hasta Yüksek Yararı ilkesine uygun olarak yönetilmelidir.

APPENDIX C PATIENT SURVEY QUESTIONS (TURKISH) - FOR THE GAMES OF FOLLOW-UP SYSTEM

FOLLOW-UP SİSTEMİ OYUN DEĞERLENDİRME SORULARI

- Follow-Up sistemi oyunlarını oynamak genel olarak tedaviye katılımımın artması için beni motive eder.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak tedavimin kalitesini artırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak tedaviye katılımımı artırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak tedavideki etkinliğimi artırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak, egzersizlerimi yapmamı kolaylaştırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamayı kolay bulurum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak çok fazla mental gayret gerektirmez.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak geleneksel tedavi yöntemleri ile egzersiz yapmaya göre daha iyi bir fikirdir.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamayı geleneksel tedavi yöntemleri ile egzersiz yapmaya göre daha olumlu bulurum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynama fikrini geleneksel tedavi yöntemleri ile egzersiz yapmaya göre daha çok severim.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi oyunlarını oynamak geleneksel tedavi yöntemleri ile egzersiz yapmaya göre daha faydalıdır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi oyunlarını oynayacağımı ön görüyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi oyunlarını oynamayı planlıyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi oyunlarını oynamaya devam edeceğimi ümit ediyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

APPENDIX D PHYSIOTHERAPIST SURVEY QUESTIONS (TURKISH) - FOR THE FEEDBACK MODULE OF FOLLOW-UP SYSTEM

FOLLOW-UP SİSTEMİ GERİ BİLDİRİM MODÜLÜ DEĞERLENDİRME SORULARI

- Genellikle, Follow-Up sistemi geri bildirim modülü hastaları uzaktan takip etmek için oldukça kullanışlıdır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülü bana oldukça kullanışlı bir servis ve bilgi sağlar.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülü yaptığım işin kalitesini geliştirir.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülü üretkenliğimi artırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülü yaptığım işte etkinliğimi artırır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülünü kullanmak benim için kolaydır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülünü kullanımını kolay buluyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülünü kullanmak çok fazla mental gayret gerektirmez.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülünü kullanmak geleneksel hasta takip metotlarına göre daha iyi bir fikirdir.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Genellikle, Follow-Up sistemi geri bildirim modülünü geleneksel hasta takip metotlarına göre daha olumlu bulurum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülü kullanma fikrini geleneksel hasta takip metotlarına göre daha çok severim.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Follow-Up sistemi geri bildirim modülünü kullanmak geleneksel hasta takip metotlarına göre daha faydalıdır.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi geri bildirim modülünü kullanmayı ön görüyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi geri bildirim modülünü kullanmayı planlıyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

- Gelecekte, Follow-Up sistemi geri bildirim modülünü kullanmaya devam etmeyi ümit ediyorum.

KESİNLİKLE KATILIYORUM (5)	KATILIYORUM (4)	NE KATILIYORUM NE KATILMIYORUM (3)	KATILMIYORUM (2)	KESİNLİKLE KATILMIYORUM (1)

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PUBLICATIONS

— Günaydin, Tugba, et al. "A Surface Electromyography Based Serious Game for Increasing Patient Participation to Physiotherapy and Rehabilitation Treatment Following Anterior Cruciate and Medial Collateral Ligaments Operations." 2018 IEEE 31st International Symposium on Computer-Based Medical Systems (CBMS). IEEE, 2018 (Günaydin et al., 2018).