TeleRehab: an Android-Based Application for Physician Referral and Physical Therapy for Patients with Frozen Shoulder and Knee Osteoarthritis Using Wearable Sensors Via Bluetooth

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Abstract-- **Missed therapy appointment is a major problem in physical rehabilitation facilities because of patients losing interest in therapy due to the struggle of going to and from the hospital numerous times a week. In addition to that, physician-to-physician communication is essential in the success of patient referral. The researchers of this study aim to connect patients, physical therapists, and physicians in a modern manner by developing an android application designed to keep track of the patient's movements while performing exercises with a wireless wearable device connected via Bluetooth attached to their arms or legs. This application also enables physicians to send referrals through e-mails for those who wish to refer patients to other physicians, online messaging and text to further patient-to-physician, patient-to-therapists, and physician-to-physician relationships.**

Keywords-- **Home-based, Telerehabilitation, Android, IOT, Bluetooth, Electronic Physician Referral, Physical Rehabilitation, Physical Therapy**

I. INTRODUCTION

Physical Rehabilitation is a therapeutic program supervised by a physical therapist designed to assist patients who suffered a sports or work-related injury, or experience conditions such as Osteoarthritis, frozen shoulder, etc. Rehabilitation usually takes place on an outpatient basis in a clinical facility, such as a hospital or physical rehabilitation facility [1]. Some patients prefer to perform their own set of prescribed exercises in their residential houses. Studies showed that over 90% of all recovery services are performed in a home-based facility [2]. In addition, physiotherapists should track and rectify patients constantly in order to prevent excessive exercise during recovery. Continuous patient-care during long-term outpatient treatment raises the pressure on physical therapists and adds costs for patients [3].This is where wireless operated wearable devices for rehabilitation come in use. The primary function of these devices is to allow therapists monitor patient's progress in distant rehabilitation, particularly mobility assessment by the use of The Internet [4]. Telerehabilitation refers to the use of technology to provide distant support, evaluation, and information to persons with physical disabilities. The implementation of telerehabilitation is an effective solution to improve the lifestyle of patients in the provision of rehabilitation services [5]. On the other hand, a health referral system is one of the most used and main basis of physician programs and its effectiveness is a factor for classifying the effectiveness of health care. All physicians included in the health-care program must provide assurance for diagnosis, treatment and rehabilitation services that makes the framework of a health referral system [6]. Results can be diagnose by therapists at any time and from anywhere through the Web – the most common mode of data transfer. Functionally, Telerehabilitation means more telemedicine creations are used for remote physical activities to provide ease of work and access for both patients and therapists [7].

The sudden growth of mobile health technology has accelerated quickly, giving patients opportunities people have never tried before. It has made a big impact in overcoming geographical and organizational limits to a better health care delivery over the years. Mobile health applications had become a way for the patients and doctors to interact by means of smartphones, in which people has welcomed it in this generation where all of us had it every day [8] [9]. All patients should always be monitored with any wearable wireless sensor devices, since sensors can effectively generate health signals to

improve communication capacity [10]. This study focuses on how effective referral system should be and how it will benefit physicians and physical rehabilitation patients. The conventional referring method that is widely used today is frail, since communication between different facilities is not much reliable. There is an insufficient information occasionally on the referred doctor making it difficult for the patient to locate them resulting to the decreased efficiency and effectiveness of this referring method. The advancements in technology today gave way to a higher level of health service providing, especially in the physical rehabilitation field. With this, physical therapists and physicians is given the opportunity to assess patients over the internet, and patients will still be able to experience consultations and physical therapy through their mobile devices.

II. METHODOLOGY

This study was conducted among various willing test subjects with different physical capabilities. Some of these participants received either intensive or non-intensive rehabilitation program before the implementation of the enhanced community quarantine. Some are persons not suffering from any physical disability.

A. System Flow

The mobile applications in this study has major functions. That is the remote mobility assessment and the electronic physician referral. The images below show the system flow for these functions.
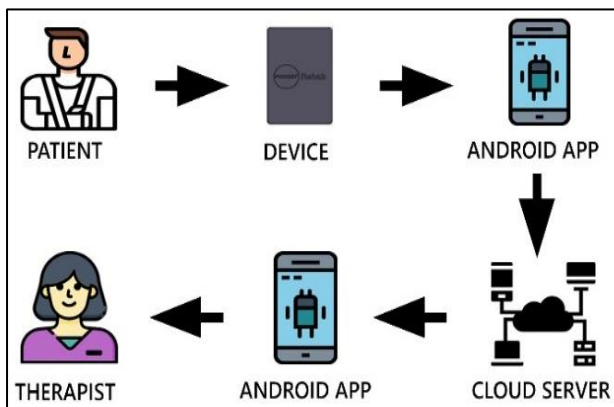

Fig.1 System Flow for Remote Mobility Assessment

Figure 1 details the remote mobility assessment function of the application. First, the 9V powered wireless wearable device is attached to the patients arms or legs. Having the wearable device paired to the android application the patient can now start performing exercises that is then stored in a real-time database and is immediately reflected in the patient's progress chart that is visible to both their therapist and attending physician.
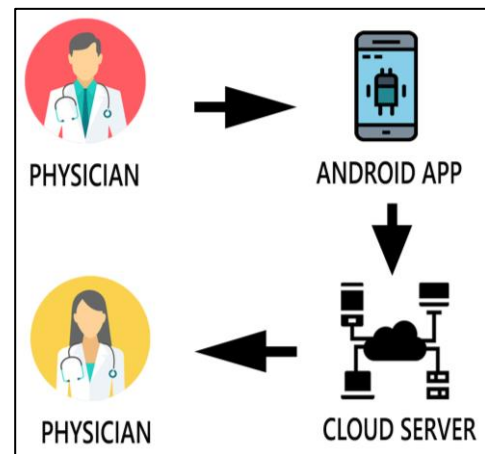

Fig. 2 System Flow for Electronic Referral

Figure 2 presents the electronic physician referral function of the application. First, the referring physician writes a formal letter to the referred physician within the application that is then sent via E-mail. The electronic physician referral of the application also enables the referring physician to send necessary documents in PDF format.

B. User Interface

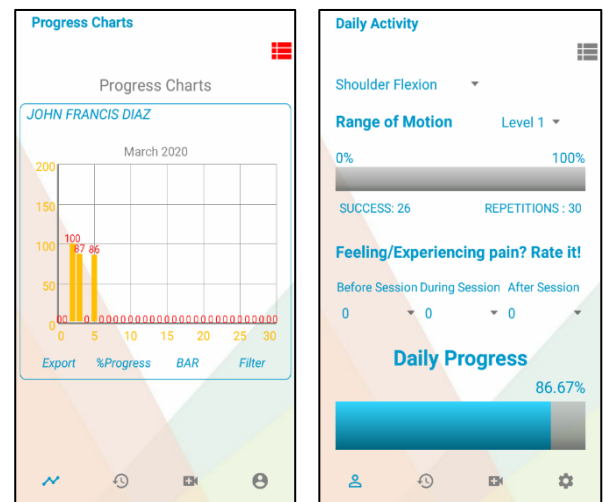The user interface of main functions of the application is shown in the images below

Fig. 3 and 4 User Interface for Remote Mobility Assessment

Figures 3 shows the progress chart visible to physical therapists and attending physicians. Figure 4 shows the graphic user interface seen by the patient during rehabilitation. In the patients' interface, it can be observed that the proponents added parameters such as difficulty levels pain experience before,

during and after exercises, success and repetitions and a progress bar, this way patients would be able to see their progress, and this would also help physicians and therapists track patients record easily.

Fig. 5 and 6 User Interface for Electronic Referral

Fig. 7 Email Interface for Electronic Referral

Figures 5 and 6 shows the user interface when a referring physician wishes to send a referral. Figure 7 shows the sample referral received via E-mail from the referring physician.

III. RESULTS

Tables 1-5 are the summarize results of the 9 patients with mobility issues

Level	Repetitions	Detected	False Positive	False Negative	Accuracy
1	200	195	0	5	97.50%
2	280	268	0	12	95.71%
3	70	60	0	10	85.71%
4	90	74	0	16	82.22%
5	120	77	0	43	64.17%

TABLE 1. REPETITIONS COUNTING RESULTS PER LEVEL ON SHOULDER FLEXION, WITH THE TOTAL CONTAINED REPETITIONS, THE REPETITIONS DETECTED BY OUR APPROACH, THE NUMBER OF FALSE POSITIVES AND FALSE NEGATIVES, AND THE PERCENTAGE ACCURACY RESULTING THEREOF.

Level	Repetitions	Detected	False Positive	False Negative	Accuracy
1	85	83	0	2	97.65%
2	90	82	0	8	91.11%
3	120	82	0	14	68.33%
4	1045	985	0	60	94.26%
5	30	30	0	0	100.00%

TABLE 2. REPETITIONS COUNTING RESULTS PER LEVEL ON SHOULDER ABDUCTION, WITH THE TOTAL CONTAINED REPETITIONS, THE REPETITIONS DETECTED BY OUR APPROACH, THE NUMBER OF FALSE POSITIVES AND FALSE NEGATIVES, AND THE PERCENTAGE ACCURACY RESULTING THEREOF.

Level	Repetitions	Detected	False Positive	False Negative	Accuracy
1	85	81	0	4	95.29%
2	90	88	0	2	97.77%
3	205	184	0	21	89.76%
4	685	664	0	21	96.93%
5	105	105	0	0	100.00%

TABLE 3. REPETITIONS COUNTING RESULTS PER LEVEL ON INWARD ROTATION, WITH THE TOTAL CONTAINED REPETITIONS, THE REPETITIONS DETECTED BY OUR APPROACH, THE NUMBER OF FALSE POSITIVES AND FALSE NEGATIVES, AND THE PERCENTAGE ACCURACY RESULTING THEREOF.

Level	Repetitions	Detected	False Positive	False Negative	Accuracy
1	90	88	0	2	97.78%
2	150	143	0	7	95.83%
3	915	842	0	73	92.02%
4	90	84	0	6	93.33%

TABLE 4. REPETITIONS COUNTING RESULTS PER LEVEL ON OUTWARD ROTATION, WITH THE TOTAL CONTAINED REPETITIONS, THE REPETITIONS DETECTED BY OUR APPROACH, THE NUMBER OF FALSE POSITIVES AND FALSE NEGATIVES, AND THE PERCENTAGE ACCURACY RESULTING THEREOF.

Level	Repetitions	Detected	False Positive	False Negative	Accuracy
1	240	239	0	1	99.58%
2	220	208	0	12	94.55%
3	535	347	0	188	64.86%
4	140	129	0	11	92.14%
5	90	76	0	14	84.44%

TABLE 5. REPETITIONS COUNTING RESULTS PER LEVEL ON LEG FLEXION, WITH THE TOTAL CONTAINED REPETITIONS, THE REPETITIONS DETECTED BY OUR APPROACH, THE NUMBER OF FALSE POSITIVES AND FALSE NEGATIVES, AND THE PERCENTAGE ACCURACY RESULTING THEREOF.

IV. CONCLUSION

This research aimed to improve the conventional physician referral and the current situation in physical rehabilitation facilities where the physical therapists to patient ratio is around 1:17 per day resulting to absentee patients or longer queue time for patients before being attended to. The purpose of this study is to allow patients to continue physical rehabilitation programs and doctor consultations whenever and wherever they want it. As conclusion, based on the analysis of the data and results gathered, the program offers multiple benefits. First, it addresses patient's immobility issues by providing an alternative channel to patients and healthcare providers for their consultation activities. Second, it improves the conventional referral method by introducing a standardized physician referral system.

V. RECOMMENDATION

This study was originally meant to be deployed in a hospital setting. Unfortunately, due to the pandemic the deployment of this study was put on hold and the proponents executed the deployment on a household setting and where overall function of the application was not maximized. In addition, the android application of the study records only one exercise per day making the overall experience of the physical rehabilitation limited. To the future researchers, the proponents of this study recommends the deployment of the study in a hospital setting to fully utilize the application potential and the improvement of some features along with the enhancement of the accuracy in all levels of the exercises. In addition, the therapists in hospitals may provide proper assistance to ensure good data and results to be recovered.

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