

Case Study

Importance of Wearable Devices in Generating Quantitative Data in Stroke Rehabilitation: An Observational Case Study

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ABSTRACT

Background: Use of digitalized methods in stroke rehabilitation is increasing. However, its effect on treatment decisions made by the physiotherapists and perceptions of patient has not been discussed extensively. **Aim:** The aim of this study was to understand the clinical relevance of objective data generated using wearable technology and its impact on treatment decisions made by the therapist for stroke patients. **Materials and Methods:** This was an observational clinical report of patients diagnosed with hemiplegia for whom a prognostic tool, Pheeze, was used to assess motor information on joint range of motion (ROM) and muscle electromyography of upper limbs. The clinical information generated by the device was used for further analysis and assessment. **Results:** A significant difference in motor parameters has been noticed between weak and healthy limbs. The data for motor parameters were severely low for weaker limbs. **Discussion:** Clinical data extracted on motor parameters from the wearable device are noncomplex to visualize and analyze and ease understanding prognosis for the patient. It strengthens the evidence available for physiotherapists to make specific treatment decisions and readily make the needed modifications in the therapy.

KEYWORDS: EMG, joint ROM, hemiplegia, physiotherapy, wearable technology

INTRODUCTION

According to the recent *statistical update fact sheet* submitted by the Global Burden of Disease, stroke is one of the leading causes of disabilities.^[1,2] Patients who have suffered from stroke present difficulties in performing activities of daily living.^[3,4] On the basis of the severity of stroke-caused disability, patients are prescribed prolonged rehabilitative care that extends from weeks to months. Incorporating a well-established rehabilitation protocol assists in the effective regain of function and mobility in stroke-related disabilities. According to guidelines provided by American Heart Association/American Stroke Association (2016), a well-established treatment protocol includes timely assessments and standardized treatment plans^[5] along with access to care and treatment information.^[6] The patient progression with the treatment is done

by tracking their motor function through timely assessments of range of motion (ROM) and muscle strength.

Recently, the increased need to digitalize telerehabilitation is seen to make patient handling methods effortless and more importantly contactless. Recordings were taken for both weak and healthy upper limbs. Rapid advancements made in the technology of health care industry increased its usage especially wearable sensors for assessments. The trend for using inertial measurement units (IMUs) for tracking

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Table 1: Case presentation of participating patients

Participants	Age	Gender	Diagnosis	Stage of stroke	Pathology
Patient A	38 years	M	Right hemiplegia	Subacute	Malignant infarction MCA occlusion
Patient B	55 years	M	Right hemiplegia	Subacute	Left cerebral hemorrhage with IV extension

MCA = middle cerebral artery

joint position and sensor technology to track muscle activity is increased simultaneously with finding novel treatment methods in physiotherapy.^[7,8] This is because they are convenient to carry, accessible, and require less time to implement. Additionally, this sensor technology is able to capture precise information of movement and make tracking of movement-related abnormalities easier.^[9] The availability of precise information on movement improves the quality of decision-making for a physiotherapist and enforces the designing of a structured therapy plan to treat disabilities. But these predictions were not evaluated for its range of benefits; to the patient in terms of duration of recovery, treatment information, and proof of recovery (printed reports of proof) as well as to the physiotherapist in terms of early identification of disability progression, and timely made decisions on therapy protocol. There is very limited research available that focused on the rate of dependency of physiotherapists on technology-fed clinical information. It is important that these benefits are evaluated as the demand in use of wearable sensor technology in stroke rehabilitation is growing fast recently. The aim of this study was to evaluate the clinical relevance of objective data generated from wearable technology. The purpose of this observational study was to understand some important aspects on role of wearables in generating clinical data and the conclusions that can be drawn which may affect physiotherapist decisions and patient perceptions during the recovery phase in stroke rehabilitation.

MATERIALS AND METHODS

This is an observational clinical study design. The clinical data were gathered on two patients who were diagnosed with Hemiplegia caused due to stroke. A brief characteristic feature of participants is shared in Table 1. Prior to the study, informed consent was signed. The patient's motor function status was tracked using the parameters—joint ROM and muscle electromyography (EMG) of both upper limbs. In Table 2, the list of included muscles and joint movements is presented. In the current study, Pheeze, a wearable device supported by an android application, was used to measure the focused motor function parameters. It's a patient activity monitor that calculates and evaluates the muscle's EMG activity and joint angle. The joint

Table 2: List of joints and muscles of the upper limb for which Pheeze readings were obtained

Joint	Movement	Muscle
Shoulder	Abduction	Deltoid
Elbow	Flexion	Biceps
Elbow	Extension	Triceps
Wrist	Flexion	Flexor carpi radialis (FCR)
Wrist	Flexion	Flexor carpi ulnaris (FCU)
Wrist	Extension	Extensor digitorum (ED)

movements tested in this study were abduction for the shoulder (S. Abduction), flexion and extension for the elbow (E. Flexion and E. Extension), and flexion and extension for the wrist (W. Flexion and W. Extension). Because of the device's feature to collect both EMG and ROM data together, the relative superficial main muscles deltoid, biceps, triceps, flexor carpi radialis (FCR), flexor carpi ulnaris (FCU), and extensor digitorum (ED) were selected for testing in this study. The assessments were taken for the upper limb while the patient is seated in the wheelchair. The measurements of the upper limb were taken in the sequence of proximal to distal manner as mentioned in Table 2; however, wrist flexion with FCU was not recorded for patient A. The top and bottom Pheeze modules were placed such that they were attached above and below the surface of the joint being evaluated. The EMG cable was connected using adhesive electrodes that were placed on the selected muscles using Seniam guidelines for skin preparation location^[10] and on the bulky surface area as recommended in previous research.^[11] Figure 1 shows Pheeze placement on patient's weaker side wrist joint for flexion movements. After placing the device, the patient was asked to perform each selective movement while the device simultaneously recorded ROM and EMG. While measuring on the healthier side of upper limb, the examining physiotherapist used manual muscle testing (MMT) with a grade of 4 or 4+ on the muscles. At the end of the assessments, the data was saved in the app where a session report with objective information on each joint and relative muscle activity is generated. The scores of ROM and EMG of both the limbs were compared and used for analysis of motor abilities of the patients using session report generated from Pheeze app. Pheeze is designed to simplify patient monitoring and assessment methods in physiotherapy.

RESULTS

The tentative scores for maximum ROM and maximum EMG are given in Table 3 for both the limbs. A significant difference was noted in the scores for hemiplegic upper limb as compared to the healthy side of the upper limb. The comparison graphs for EMG and ROM are as shown in Figures 2, 3, 4, and 5, respectively. The line graphs are color coded with blue referring hemiplegic limb and green referring to healthy or normal upper limb of the patients. A session recording of affected biceps muscle of participant is as shown in Figure 6,



Figure 1: Pheeze placement on effected wrist joint of the patient

which is retrieved from the session report generated by the Pheeze device.

DISCUSSION

Emerging technology urged patient care service providers to digitalize the existing treatment methods in health care field.^[12] However, there is limited information available that discussed on the impact of technology-derived information on prescribing therapy by physiotherapists in stroke rehabilitation. The purpose of this observational study was to understand some important aspects on role of quantitative data generated by wearables and the conclusions that can be drawn which may affect physiotherapist decisions and patient perceptions during recovery phase in stroke rehabilitation. This is done by using Pheeze device that provides objective clinical information of motor variables. The motor variables were compared for both involved and uninvolved upper limbs of the patients.

The Pheeze generated clinical data has shown a significant difference between the affected and unaffected upper limbs of the patients. The EMG values

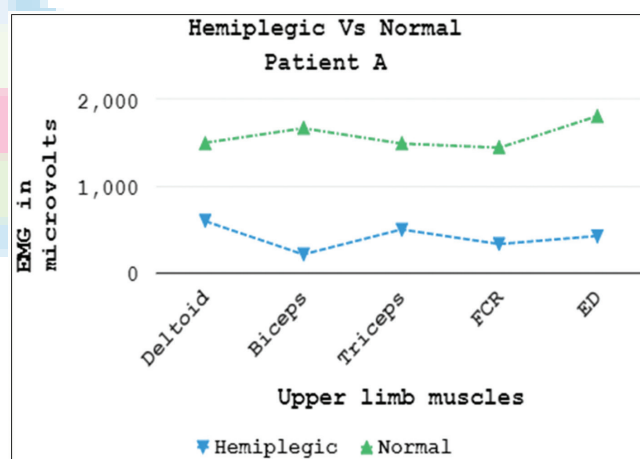


Figure 2: Comparing Pheeze EMG scores of upper limb muscles in Patient A (blue: hemiplegic and green: normal)

Table 3: Objective information of ROM and EMG as shown in session report generated by Pheeze for hemiplegic (right) and normal (left) upper limbs

Patient A				Patient B			
EMG (microvolts)		Max. ROM (degrees)		EMG (microvolts)		Max. ROM (degrees)	
Right	Left	Right	Left	Right	Left	Right	Left
594	1498	90	180	38	2346	55	151
209	1666	40	98	907	1681	59	118
498	1489	48	100	596	546	68	106
329	1441	30	43	42	755	26	55
—	—	—	—	777	1196	37	44
423	1806	59	78	355	317	35	7

EMG = electromyography, ROM = range of motion

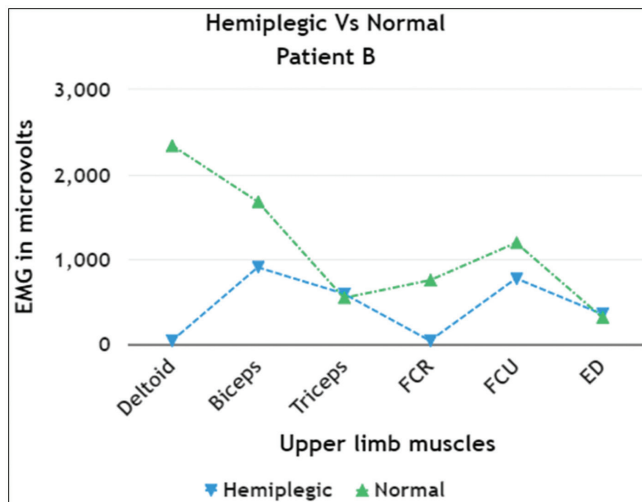


Figure 3: Comparing Pheeze EMG scores of upper limb muscles (blue: hemiplegic and green: normal)

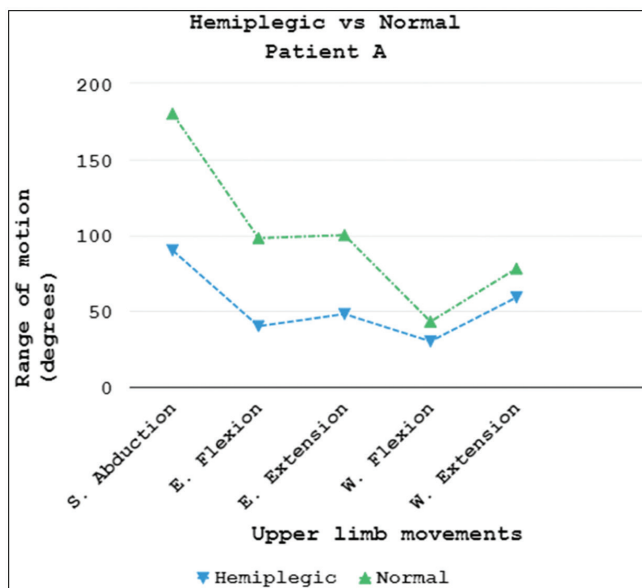


Figure 4: Comparing Pheeze ROM scores of upper limb muscles in patient A (blue: hemiplegic and green: normal)

when compared to the normal unaffected side muscles, it is seen that the muscles tested were remarkably weak in the affected limbs. A weak muscle firing is seen in the affected limb for all the muscles in patient A, whereas the weak muscle firing values are shown for deltoid, biceps, and FCR in patient B as compared to their respective healthy contralateral limbs as seen in Figure 4. The conclusions that can be drawn from the results are that the weak muscle activity is present for deltoid, biceps, and FCR and not for ED in the affected side as compared to his normal limb in patient B. This exception for ED suggests that the muscle might not have been equally affected with stroke physiology as that of other muscles of the upper limb. As it is proven

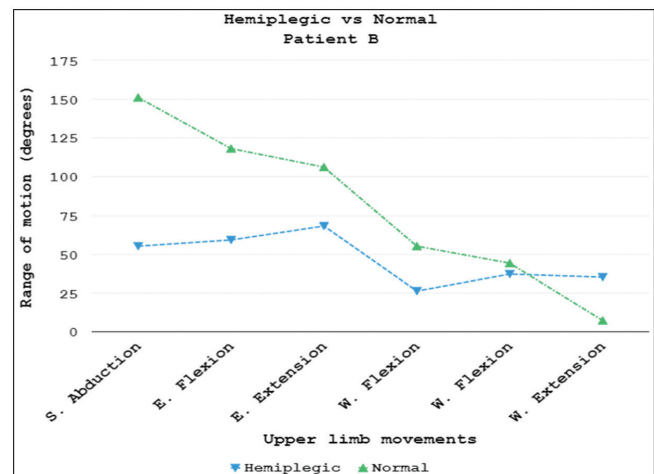


Figure 5: Comparing Pheeze ROM scores of upper limb muscles in patient B (blue: hemiplegic and green: normal)

that strength training of antagonist muscles can have positive affect agonist muscles.^[13,14] Therefore, from the findings from Pheeze report physiotherapist can include specific ED training program to improve the performance of wrist flexors muscle. The same principle can be applied to train triceps muscle as the EMG score was almost similar to the normal limb in patient B. But it is noticed only as a gradual increase in muscle firing during the initiation of movement [Figures 6 and 7]. This need to be understood more by monitoring the muscle continuously which is only possible by using digital methods of sEMG devices. These decisions could not have been made using conventional methods of assessment. Another conclusion that can be drawn is that the joint ROM needs to be focused on more while designing treatment protocol for patient A, especially for shoulder and elbow movements, whereas the ROM values were nearly normal for almost all the measured joints for patient B. The ROM score recorded for unaffected side of wrist extension movement is only 7° in patient B. This is because the examining therapist was resisting the movement with MMT grade 4 up to grade 4+ which increased EMG activity but limited free joint range of motion as seen in Figure 4 for patient B. Thus, having convenient assessment tools that are able to retrieve objective information on patient motor function abilities enables early problem identification and in designing treatment plan in less time with prioritizing the goals for various joints and muscles.

The patient's perception of an effective physiotherapy depends on factors like communication, patient education given by the physiotherapist, physiotherapist's expertise, and patient-therapist relationship.^[15,16] In a cross-sectional study conducted on patient's perceptions, it is found that the treatment information

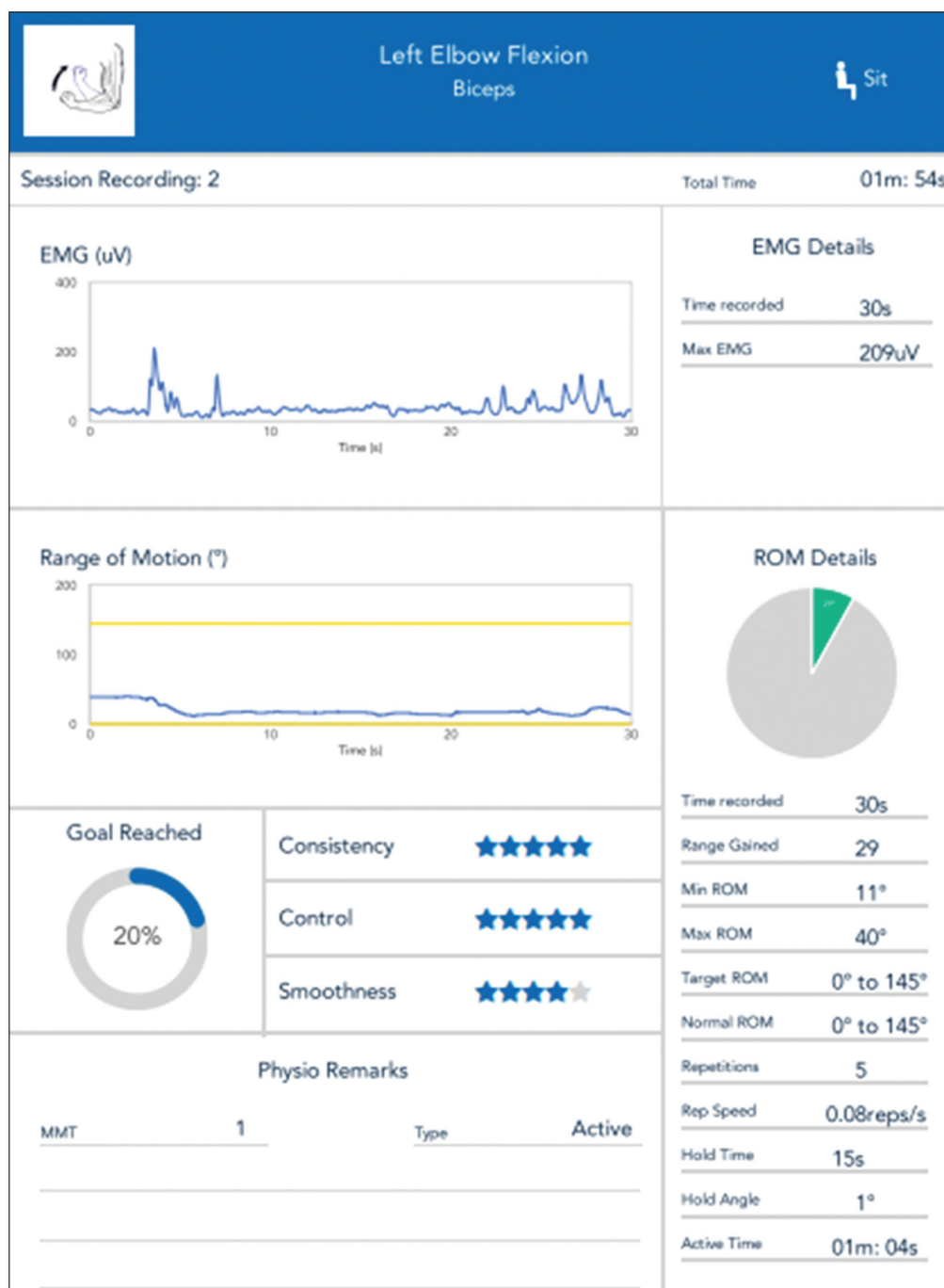


Figure 6: Session recording of affected elbow joint flexion retrieved from Pheeze session report

provided to patient is considered as an important factor for affective outcomes of treatment. That information should include patients' current health status, their treatment course, and the duration of treatment.^[17,18] This requirement calls for report-generating technology that can emphasize patient's perception on quality of care provided in stroke rehabilitation. Therefore, the digitalized therapy methods that can share treatment information in simple ways to the patient or primary caregiver is highly recommended as it helps in increasing

their overall performance.^[19-21] From the results of this study, it is seen that the patient perceptions can be enhanced positively with the availability of their own therapy and recovery information in the form of reports. Using the objective information has been presented as an easy way to convince the patient that the progress has been happening and there is some residual electrical firing left in the muscle that may have seemed to be gone completely to the naked eye. Hence, digital technology improves patient's performance, experience,

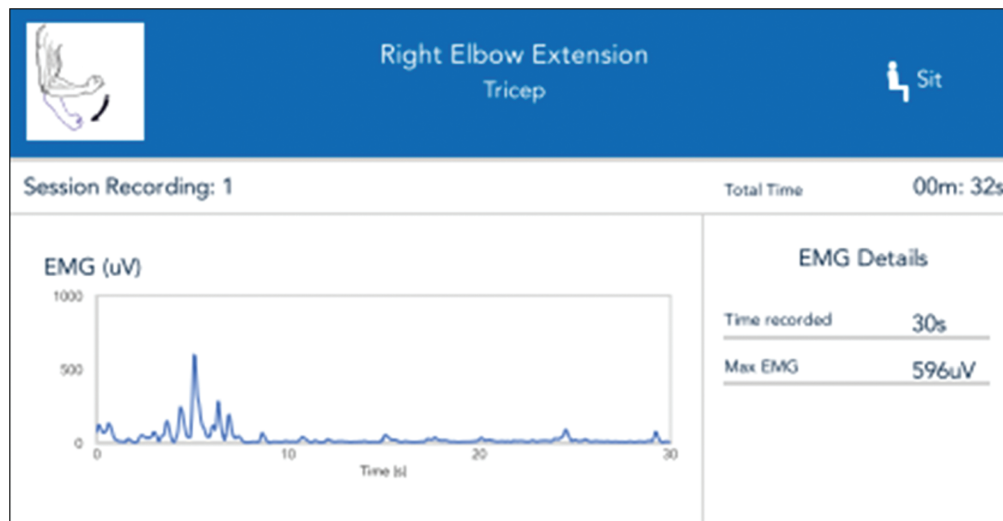


Figure 7: Pheeze EMG graph showing muscle firing seen in Triceps for few seconds in patient B

and keeps them motivated through the therapy sessions ultimately leading to effective recovery.

In the current study, the physiotherapist used objective data to assess the motor function ability of the patients and customized the exercise plan as per the need. Therefore, it can be concluded that with the use of wearable technology-provided clinical data the treatment decisions can become more goal specific, timely, accurate, and more importantly, effective. Furthermore, the availability of session reports helped the patients in understanding their current status of their motor function of affected limb as compared to the normal limb. This again would not have been possible using conventional methods. Additionally, during the exercise session, the prescribed number of repetitions were calculated in the device itself. This feature helped the patient to focus more on the quality of movement performed rather than just finishing the goal of repetitions.

CONCLUSION

Hence, it can be concluded that incorporation of digital treatment approaches add value to the treatment decisions made by physiotherapists for patients in stroke rehabilitation. Because the demand of using wearable sensor technology in stroke rehabilitation is growing fast recently, there is a need to have devices like Pheeze that evaluate the effects of using quantitative data for treatment decisions made in a clinical setting. Future research should focus on evaluating the effectiveness of digital clinical data by including more patients. The digital device-generated data enhance the therapist's treatment decisions made for the patients that will ultimately help in accelerating overall duration of recovery process.

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Conflicts of interest

There are no conflicts of interests.

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