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Quantitative Measure of The Functional Ability Index Using Activity of Daily Living Based on Motor Activity Log

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ABSTRACT

The assessment in evaluating a stroke patient's ability done by the doctor and therapist provides an important information that is valuable in guiding treatment plans, determining the appropriate levels of stroke severity, and identifying areas where interventions are needed to improve a patient's functional ability. However, the current manual method for assessing stroke patients in occupational therapy is subjective and inconsistent, as it relies on the therapist's individual expertise and experience. To address this issue, this paper presents a pilot study on a quantitative measure of Functional Ability Index (FAI) utilising activities of daily living (ADL) based on the Motor Activity Log (MAL) clinical assessment. The Pearson correlation technique is implemented to measure the relationship between variables and normalisation function is adopted for stroke patient's FAI estimation to describe their capability. Ten ADLs from MAL assessment have been selected for this study. Data on force exerted, arm movement, equipment motion during ADLs, and the time duration to execute the ADL task have been collected from 30 healthy subjects and 56 stroke patients. Sensors of force, IMU, encoder, and distance have been employed for this purpose. The estimated FAI's are then compared to the manually scored given by the therapists. The results indicate that the highest achieved accuracy is 77% for the ADL 'Fan Regulator'. These results demonstrate the feasibility of the method for establishing a quantitative measure of FAI.

Keywords: Activity of Daily Living; Motor Activity Log; Occupational Therapy; Statistical Analysis; Stroke Rehabilitation

INTRODUCTION

Stroke is a brain attack that occurs when there is a disruption or cessation of blood flow to the brain, leading to the death of brain cells and potential damage (Langhorne et al. 2011)(Lo et al. 2005). Over 13.7 million annual stroke episodes worldwide this has grown into a significant global concern. There are three primary stages of a stroke: transient ischemic attack (TIA), ischemic stroke, and hemorrhagic stroke (Corrigan et al. 2013)(Petty et al. 2021). TIA is a brief interruption in blood supply to the brain, serving as a warning sign for potential future strokes. Ischemic Stroke, the second stage, is triggered by a blocked artery in the brain, often due to blood clots or other particles. It represents the majority of strokes and leads to long-term disability or death. The third stage is Hemorrhagic Stroke, characterised by the leakage or rupture of an artery in the brain, exerting excessive pressure on brain cells and causing damage (Smith & Eskey, 2011)(Reker et al. 2001)(S. Y. Mounis & Azlan, 2019).

Stroke risk factors comprise high blood pressure, heart disease, diabetes, smoking, high cholesterol, obesity, lack of exercise, and excessive alcohol use (Saini & Gurvendra 2022). Certain risk factors are arrangeable to change, treatment, or medical management, providing an opportunity to reduce the likelihood of a stroke attack (Bays et al. 2021). Stroke symptoms vary depending on the affected brain area but commonly include facial drooping, arm weakness, and speech difficulty (Upadhyay 2022). Early detection and treatment of stroke symptoms are crucial, as they can significantly improve patient treatment outcomes and reduce the risk of long-term disability (Chang et al. 2022).

In this paper, Functional Ability Index (FAI) is defined as the assessment score in evaluating the post-stroke patient's functional ability in performing the tasks in daily living activities. Stroke assessment scale such as Action Research Arm Test (ARAT), Fugl-Meyer Assessment (FMA), and Motor Assessment Scale (MAS) assist the therapists in identifying and assessing stroke patient FAI, a crucial element in determining appropriate treatment and improving patient outcomes. It is essential to note that the approach may differ for each patient, depending on the extent of their stroke (Malcolm et al. 2009). Therapists commonly assess motor function in post-stroke patients manually (Housman et al. 2009). However, manual assessments face several challenges, as they are inherently subjective and heavily depend on the therapist's individual experiences (Khairuddin et al. 2017).

To address this issue, the existing qualitative approach needs to be improved by incorporating more quantitative methods. Diverse research initiatives have been undertaken, including the development of prototypes and the utilisation of sensors that align with this objective. Table 1 illustrates the current research in this direction. Despite those studies, to the best of author's knowledge, there has been no dedicated research on the usage of appropriate sensors for assessing post-stroke patients while performing Activity of Daily Living (ADL). The effective implementation of ADL tasks contributes to the improvement of fine and gross motor skills, coordination, and balance, which are often affected by a stroke.

This paper presents a quantitative measure of the functional ability index (FAI) using activity of daily living (ADL) based on Motor Activity Log (MAL) assessment scale for assessing stroke patient's capability in performing ADL during rehabilitation. Stroke patient assessment involves on measuring the force exerted by the patient and the time taken to complete specific tasks. These two key parameters are recorded as subjects participate in ADLs and the data are systematically collected along with other related parameters identified as relevant to this study. Data collection involving stroke patients and healthy subjects has been conducted for this purpose. The Pearson correlation technique is performed to measure the linear relationship of the significant correlation between the input sensor reading to the MAL output score. The FAI has been formulated by adopting normalisation function method. Subsequently, the computed FAI is compared to the manual therapist rating during the subjects' engagement the therapy.

The paper is organised as follows: Section 2 introduces the ADLs equipment setup and data collection, providing a detailed explanation of the MAL assessment, ADLs selection, recorded parameters, sensors utilised, and the data logger employed. Section 3 focuses on FAI formulation, elaborating on data analysis using Pearson correlation method and the implementation of Normalisation Function technique in formulating the FAI to describe the stroke patient's functional ability. Section 4 presents the Results and Discussion of the data analysis, offering the insights into the findings. Finally, Section 5 concludes the overall work, summarising key insights, and suggesting directions for future research.

TABLE 1. Recent research focuses on quantitative strokes assessment

Authors	Standard Clinical Assessment	Develop Prototype	Measured Parameter	Subjects
Ahmad Puzi et al. (2017)	MAS	1-DOF robot	Torque and angle	2 stroke patients
S. Y. A. Mounis et al. (2019)	WMFT	2-DOF robot	Torque and angle	7 healthy subjects 3 stroke patients
S. Y. A. Mounis et al. (2020)	ARAT, WMFT	1 DOF exoskeleton	Torque, strain and angle	15 stroke patients
Tsai et al. 2019)	MAS	DexoHand	Output voltage and cable tension	6 healthy subjects 18 stroke patients
Chua et al. (2020)	6MWT, 10MWT, BBS, FAC	VASST II	Walking speed, capacity and endurance	11 stroke patients
Poliero et al. (2018)	Nil	XoSoft	Torque, angle, power and flexibility	1 healthy subject 1 stroke patient

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Chen et al. (2021)	FMA,Kendall MMT, MBI	BCI-FES system	Brainwave	32 stroke patients
Hsiao et al. (2013)	BBT	Digital BBT	Unilateral gross manual dexterity	Nil
Hsu et al. (2012)	PPT, JTHF	CERB	Pinch force	14 stroke patients
Peng et al. (2017)	FMA	CASIA-ARM	Torque and force	24 stroke patients
Bobin et al. (2018)	ARAT	Smart cup; SyMPATHy	Force and arm activity	9 stroke patients

ADLS EQUIPMENT SETUP AND DATA COLLECTION

The MAL has been employed as the standard assessment scale in this paper. It is designed to assess the amount and quality of use of the affected upper extremity in individuals recovering from stroke in performing ADLs. Amount of Use (AOU) measures how much the affected limb is used in various activities of daily living, such as reaching, grasping, or manipulating objects over a specified period. Quality of Movement (QOM) assesses how well the subject used the affected limb during activities. MAL ratings are divided into 6 scores ranging from 0 to 6. Table 2 describes the details of MAL scores for AOU and QOM.

Ten ADLs have been selected from the MAL assessment grounded on their essential nature in daily life based on advice after consulting experienced therapists from Hospital Selayang Rehabilitation Center, Batu Caves, Selangor, to ensure their significance in rehabilitation treatment in preparing patients to return to their normal lives. Table 3 shows these 10 ADLs and their assigned terminology in this paper.

Data are collected as the subjects perform the ADLs as outlined in Table 3. Subjects are instructed to imitate real-life applications using the provided ADLs equipment. The data recorded include the force exerted (Force) and the time taken (Time) by the subjects to complete each ADL. Additionally, readings of arm moment (Rotation A & Rotation B) and ADL equipment motion (Motion) are also recorded as they are considered relevant parameters to support this study.

All ADLs have been equipped with specific sensors as summarised in Table 4 to obtain subject parameter readings during the performance of ADLs tasks. The force sensor used is a force-sensing resistor (FSR). FSR is a resistive pressure sensor that changes its electrical resistance in response to applied force or pressure. The sensor is highly flexible, making it well-suited for integration into various surfaces on ADLs. The FSR sensor provides measurements in Newtons for the applied force.

TABLE 2. The MAL score rating (McDermott, 2019)

Score	Amount of Use (AOU)	Quality of Movement (QOM)
0	Did not use the weaker arm (**Not Used**).	The weaker arm was not used at all for that activity (**Never**).
1	Occasionally used the weaker arm, but only very rarely (**Very Rarely**).	The weaker arm was moved during the activity but was not very helpful (**Very Poor**).
2	Sometimes used the weaker arm but did the activity most of the time with the stronger arm (**Very Rarely**).	The weaker arm was use during the activity but needed some help from the stronger arm or moved very slowly or with difficulty (**Poor**).
3	Used the weaker arm about half as much as before the stroke (**Half Pre-Stroke**).	The weaker arm was used for that activity, but the movements were slow or were made only with some effort (**Fair**).
4	Used the weaker arm almost as much as before the stroke (**3/4 Pre-Stroke**).	The movements made by the weaker arm were almost normal but not quite as fast or accurate as normal (**Almost Normal**).
5	Used the weaker arm as often as before the stroke (**Same as Pre-Stroke**).	The ability to use the weaker arm for that activity was as good as before the stroke (**Normal**).

TABLE 3. ADLs and the assigned terminology

No	ADLs of MAL	Assigned Terminology
1	Engage and release plug top	Plug Top
2	Turning on a light switch	Switch
3	Turning a fan regulator	Fan Regulator
4	Turning a water faucet	Water Faucet
5	Turning a doorknob	Doorknob
6	Opening a drawer	Drawer
7	Opening a door	Door
8	Combing a hair	Comb
9	Using a spoon for eating	Spoon
10	Brushing a tooth	Toothbrush

TABLE 4. ADLs equipment sensors.

No	ADLs	Equipment sensor	Reading
1	Plug Top	FSR, digital input	Newton (N), 0/1
2	Switch	FSR, digital input	Newton (N), 0/1
3	Fan Regulator	FSR, digital input	Newton (N), 0/1
4	Water Faucet	FSR, rotary encoder	Newton (N), Angle (o)
5	Doorknob	FSR, ToF	Newton (N), Millimeter (mm)
6	Drawer	FSR, ultrasonic	Newton (N), Centimeter (cm)
7	Door	FSR, rotary encoder	Newton (N), Angle (o)
8	Comb	FSR	Newton (N)
9	Spoon	FSR	Newton (N)
10	Toothbrush	FSR	Newton (N)

Digital input refers to the signal provided by ADLs themselves to describe their state, which is directly connected to the microcontroller for interpretation. A signal of 0 indicates that the ADLs have not yet been performed, while a signal of 1 indicates that the ADLs have been successfully executed. The rotary encoder sensor is used to measure the rotational angle position in degrees. 360-degree rotary encoders are utilised to provide readings on the rotation of the water faucet lever and the degree of door opening performed by the subject. Distance sensors are employed for ADLs Doorknob and Drawer. Different types of distance sensors are used because of their different applications. For the Doorknob task, a Time-of-Flight (ToF) VL53L0X ranging sensor is used for optimal efficiency. The sensor readings fall within the range of 0mm to 15mm, where 0mm indicates no rotation of the knob, and 15mm corresponds to a complete turn. For the Drawer task, an ultrasonic distance sensor is used, mounted on the drawer base. The recorded distance (cm) increases proportionally with a larger drawer opening.

Sensors are also employed on the subject's wrist to monitor their arm movement during ADLs execution. The MPU6050 3-axis acceleration gyroscope module measures rotation in the A and B directions. Housed in a protective casing and securely fastened with a strap to mimic the wearing of a wristwatch, ensuring the subject's comfort and minimising disruption caused by electronic equipment. An advantageous of this sensor is its ability to capture hand movements simultaneously along two axes. Figure 1 illustrates the orientations of recorded rotation in the A and B directions.

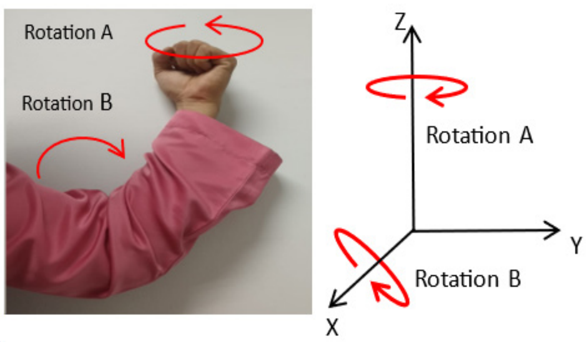

FIGURE 1. The rotation A and B directions.

Time parameters are captured utilising the data logger method, with all input parameters are recorded at 500-millisecond intervals. This data logger is seamlessly integrated with the ESP32 Wrover B microcontroller, which takes on the centre of coordinating all sensors.

The data collection involves two groups of subjects where 30 subjects are randomly selected healthy individuals from the Machinery Technology Centre of SIRIM Berhad in Rasa, Selangor, and 56 stroke survivors are from Sultan Ahmad Shah Medical Centre (SASMEC), IIUM, Kuantan, Pahang. The IIUM Research Ethics Committee (IREC) has granted approval for data collection from stroke patients under ID number IREC 2023-078.

FAI ESTIMATION

The FAI is a measurement tool used in stroke assessment to provide a comprehensive and standardised evaluation of the stroke patient's functional abilities (Li et al. 2003). It helps to monitor the stroke patient's progress by tracking improvements or declines in functional abilities over time (Andersen et al. 2004). By identifying areas of strength and areas needing improvement, it assists in targeting specific functional deficits to maximize recovery potential and optimize stroke recovery outcomes (Sanner & Kosha, 1999).

Since this study is based on the MAL assessment scale, which consists of two output scores: AOU and QOM, the Pearson correlation analysis is performed to measure the strength and direction of the linear relationship between input variables such as Force, Rotation A, Rotation B, Motion, and Time, to the output scores AOU and QOM. Only parameter data with a high significant correlation ($p \leq 0.001$) are considered for subsequent calculations. IBM SPSS Statistics Version 27 was utilised for this analysis.

Then, the FAI is formulated based on Normalisation Function to enable a standardised and consistent approach in assessing stroke patients. The equation for this function is as follows (S. Y. A. Mounis et al. 2019)

$$S_i = N_{min} + [\frac{X - X_{min}}{X_{max} - X_{min}}(N - N_{min})] \quad (1)$$

where S_i represents the calculated FAI using the normalisation function, N_{min} is the minimum score in MAL, which is 0. The variable X denotes the measured parameter, X_{min} is the minimum measured parameter in the datasets, and N_{max} is the maximum measured parameter in those sets. N is the maximum score in MAL, which is 5. By adapting the formula to the MAL score, equation (1) is simplified as:

$$S_i = [\frac{X - X_{min}}{X_{max} - X_{min}}(5)] \quad (2)$$

X_{min} is derived from the average of the lowest 10 data points within the stroke patient set, while X_{max} is obtained from the average of the data from the healthy subjects, comprising 30 individuals. Therefore, the normalisation function for the Force parameter, $S_{i,F}$ is expressed as:

$$S_{i,F} = \left[\frac{F_s}{F_h}(5)\right] = 5(F_s F_h^{-1}) \quad (3)$$

where F_s (substituted for $X–X_{min}$) represents the Force of the stroke patient minus the average of the minimum 10 Forces recorded from stroke patients, and F_h (substituted for $X_{max}–X_{min}$) is the average Force of the 30 healthy subjects minus the average of the minimum 10 Forces recorded from stroke patients. The calculated $S_{i,F}$ is capped at the maximum of 5, in accordance with the MAL scoring. The same principle applies to the normalisation function for the Motion parameter, $S_{i,M}$.

$$S_{i,M} = \left[\frac{M_s}{M_h}(5)\right] = 5(M_s M_h^{-1}) \quad (4)$$

where M_s (substituted for $X–X_{min}$) represents the Motion moved by the stroke patient minus the average of the minimum 10 Motion recorded from stroke patients, and M_h (substituted for $X_{max}–X_{min}$) is the average Motion of the 30 healthy subjects minus the average of the minimum 10 Motion recorded from stroke patients. Similar to the Force parameter, the calculated $S_{i,M}$ is limited to a maximum value of 5, in line with the MAL scoring standard.

For the Rotation A, Rotation B, and Time parameters, the character data is inversely related compared to the Force and Motion. According to therapist ratings, a higher subject score corresponds to less arm movement in Rotation A and Rotation B, as well as Time for a given ADLs task. Therefore, the normalisation functions for the Rotation A can be written as:

$$S_{i,A} = \left[\frac{X_h}{X_s}(5)\right] = 5(X_h X_s^{-1}) \quad (5)$$

Similarly, for Rotation B,

$$S_{i,B} = \left[\frac{Y_h}{Y_s}(5)\right] = 5(Y_h Y_s^{-1}) \quad (6)$$

and finally for the Time,

$$S_{i,T} = \left[\frac{T_h}{T_s}(5)\right] = 5(T_h T_s^{-1}) \quad (7)$$

$S_{i,A}$, $S_{i,B}$ and $S_{i,T}$ are normalisation functions for the parameters Rotation A, Rotation B, and Time, respectively. X_h, Y_h dan T_h (substituted for $X–X_{min}$) represent the average of Rotation A, Rotation B, and Time parameters respectively recorded by 30 healthy subjects minus the average of the minimum ten Rotation A, Rotation B, and Time parameters of stroke patient. X_s, Y_s, T_s (substituted for $X_{max}–X_{min}$) is the average of Rotation A, Rotation B, and Time by 30 healthy subjects respectively minus the average of the minimum ten Rotation A, Rotation B, and Time, respectively recorded from stroke patients.

The scores for all the three parameters are also capped at a maximum of 5, following the MAL scoring standard.

The FAI is computed based on the average of the normalised values derived from significant correlations with its output parameters. Subsequently, this calculated value is compared with the MAL scores provided by therapists manually. The different between the calculated score and the score rated by the therapist are determined using the Root Mean Square Error (RMSE). A higher RMSE value indicates a higher error, depicting a greater gap between the calculated FAI value and the therapist rating.

RESULT AND DISCUSSION

The dataset contains the data from 56 stroke patients undergoing a quantitative assessment of FAI through the utilisation of a Pearson correlation and normalisation function. The input parameters which are Force, Rotation A, Rotation B, Motion and Time demonstrating a significant correlation, determined by a significance value of 0.001 or lower ($p \leq 0.001$), to output parameters which are AOU or QOM, are considered for calculations using the normalisation function technique. Table 5 presents the results of the Pearson correlation analysis, with bold values indicating data that meets the criteria for correlation significance.

TABLE 5. The Pearson correlation analysis.

ADL	Output	Input				
		Force	Rotation A	Rotation B	Motion	Time
Plug Top	AOU	< 0.001	0.829	0.028	< 0.001	< 0.001
	QOM	< 0.001	0.589	< 0.001	< 0.001	< 0.001
Switch	AOU	0.022	< 0.001	< 0.001	< 0.001	< 0.001
	QOM	0.050	< 0.001	< 0.001	< 0.001	< 0.001
Fan Regulator	AOU	< 0.001	0.019	0.845	< 0.001	0.002
	QOM	< 0.001	0.004	0.968	< 0.001	< 0.001
Water Faucet	AOU	0.020	< 0.001	< 0.001	-	< 0.001
	QOM	< 0.001	< 0.001	< 0.001	-	< 0.001
Doorknob	AOU	< 0.001	0.628	< 0.001	< 0.001	< 0.001
	QOM	< 0.001	0.865	< 0.001	< 0.001	< 0.001
Drawer	AOU	< 0.001	< 0.001	0.244	0.017	< 0.001
	QOM	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Door	AOU	0.043	< 0.001	< 0.001	0.018	< 0.001
	QOM	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001
Comb	AOU	0.001	0.604	0.024	-	< 0.001
	QOM	< 0.001	0.807	0.023	-	< 0.001
Spoon	AOU	0.046	0.186	< 0.001	-	< 0.001
	QOM	0.013	0.688	< 0.001	-	< 0.001
Toothbrush	AOU	< 0.001	0.011	< 0.001	-	< 0.001
	QOM	< 0.001	0.086	< 0.001	-	< 0.001

The Pearson correlation analysis on Motion data for ADL Water Faucet cannot be executed as all subjects have successfully completed the activity. The analysis also cannot be performed for Comb, Spoon, and Toothbrush due to the nonexistence of motion sensor attached to the respective devices for these activities.

The input parameter Force shows no significant correlation with the outcomes of Switch and Spoon for both AOU and QOM. There are also has no significant correlation with the outputs AOU Water Faucet and AOU Door. Based on the observation during the data collection process, the lack of correlation in ADL Switch can be attributed to its singular and quickly executed action, resulting in minimal deviation in input across subject scores. As for the Spoon, the differences in the techniques employed by each subject contribute to the observed low level of significant correlation. The input parameter Force also exhibits less significant correlation for output AOU Water Faucet, given that minimal force is required to complete this activity and all subjects successfully complete it. For AOU Door, the Force input shows a lack of a significant correlation is attributed to the motion input variation, which also did not exhibit significance correlation.

The measured arm movements, represented by Rotation A and Rotation B, exhibit varying levels of significance in correlation. Rotation A shows the least significant correlation compared to Rotation B and other parameters. This is attributed to the fact that most of the selected ADLs demand minimal movement at the wrist, resulting in constrained

variation in the range of motion for Rotation A. In contrast, Rotation B representing the range of motion at the elbow, demonstrates higher significant correlation results. This is because the execution of selected ADLs are mainly involve movements of elbow, leading to increased variability in Rotation B.

The results for the Motion parameter input show the high significant correlation. Only the outputs for AOU Drawer and AOU Door lack a significant correlation. This indicates that the input parameter Motion highly influences the output. The input parameter Time demonstrated a significant correlation for almost all ADLs, except for the output AOU for Fan Regulator. Similar to the Motion input parameter, the Time input parameter also exhibits a responsive correlation to output variations based on the stroke level of the subjects.

The FAI are calculated using the normalisation function method based on Pearson correlation result. For ADL Plug Top, the calculated FAI for AOU output is determined by the normalisation of Force, Motion, and Time parameters. For the QOM output, the input parameters Force, Rotation A, Rotation B, Motion, and Time are taken into account in the normalisation formulation based on the Pearson correlation results in Table 6.

The difference between the FAI calculated using the normalisation equation and therapist assessment is determined using the root mean square error (RMSE) method. Table 6 displays the RMSE for all ADLs performed by the 56 stroke patients. RMSE value indicates less error between the two values, signifying higher accuracy. Based on the RMSE values, error and accuracy percentages are provided, offering insights into the precision of the results.

It is observed that the lowest error is in AOU Fan Regulator, at 23%, indicating the highest accuracy of 77%. This suggests that the difference between manual therapist ratings and the FAI calculated using the normalisation function for ADL Fan Regulator is the closest compared to other activities. From the results, it can be seen that the AOU Switch indicates the highest error of 50%, with a corresponding accuracy of 50%. The errors obtained from the calculation based on the normalisation function method range from 23% to 50%, and the accuracies vary between 50% and 77%. This suggests that further improvement is required for the FAI calculation method for automatic scoring to achieve lower errors and consequently attain to optimal accuracy.

TABLE 6. RMSE, error and accuracy of FAI compared to therapist rating

ADL	AOU			QOM		
	RMSE	Error (%)	Accuracy (%)	RMSE	Error (%)	Accuracy (%)
Plug Top	1.664	33	67	1.818	36	64
Switch	2.486	50	50	1.506	30	70
Fan Regulator	1.173	23	77	1.445	29	71
Water Faucet	1.631	33	67	1.336	27	73
Doorknob	1.302	26	74	1.275	25	75
Drawer	1.783	36	64	1.669	33	67

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Door	2.113	42	58	1.615	32	68
Spoon	2.171	43	57	2.113	42	58
Comb	2.004	40	60	1.500	30	70
Toothbrush	1.706	34	66	1.592	32	68

CONCLUSION

This paper presents the outcomes of a study focusing on the quantitative measure of the FAI using ADL based on MAL assessment. The Pearson correlation and the Normalisation Function technique are employed to calculate the FAI quantitatively. Initially, Pearson correlation analysis is performed to gauge the influence of input which are the Force, Rotation A, Rotation B, Motion and Time parameters on the output which are AOU and QOM score. Based on the Pearson correlation analysis results, the FAI computed employing Normalisation Function technique. This study focuses on 10 ADLs from the MAL assessment. A total of 86 subjects, including 56 stroke patients and 30 healthy individuals, participated in the study. The force sensors, encoder sensors, distance sensors, and IMU sensor are attached to the selected ADL devices and the subjects' hands to collect input parameter readings. The output parameters, specifically AOU and QOM ratings, are acquired from certified therapists. The calculated FAI is then compared to the rated MAL score provided by the therapists. This method has achieved an accuracy ranging from 50% to 77%. Further enhancements to refine the calculation method are required to improve the accuracy. Future work includes on implementing more advanced formulation. The upcoming studies also need to include a larger dataset that consists of both healthy individuals and stroke patients to increase the reliability and accuracy of the results.

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DECLARATION OF COMPETING INTEREST

None

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