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Task and Kinematic Parameters for Upper Limb Stroke Patient: A Review

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ABSTRACT. The development of robotics technology has now been used to assist the rehabilitation therapy process of stroke patients. This far, the progress of therapy patients has been observed qualitatively and quantitatively with several clinical assessments such as Fuegl Meyer, Barthel Index, Motor Function Index, etc. This paper aims to provide a review of stroke patient progress evaluation measurements using kinematic parameters using elbow and shoulder robotic therapy devices and provide an overview of the types of exercises performed on the robotic therapy interface on the motor and cognitive development of stroke patients. Thirty publications that used kinematic parameters as the basis for assessing the development of stroke patients were included, there were 81 kinematic parameters from all the studies reviewed, based on ICF 53 of which were included in the Body Functions and Structures (BFS) classification, and 28 others were included in the Activities and Participation (AP) classification. Several studies showed a good correlation between the measurement of kinematic parameters and clinical assessment ($P<0.05$), in addition to good correlation some kinematic parameters also showed good reliability (ICC, $r>0.7$; $P<0.05$).

Keywords: Kinematic Parameters, Robotic Therapy, Assessment, Stroke, Upper Limb

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1. INTRODUCTION

A person affected by stroke generally has difficulty performing activities of daily living (ADL) because it requires a combination of physical, cognitive, and perceptual problems [1], [2], rehabilitation is the main treatment carried out for this disease, this rehabilitation process trains patients to relearn to use their body parts again to restore their independence.

Stroke rehabilitation has a limited time frame, [3], [4] have demonstrated that rehabilitation can produce significant improvements if it is administered within 13 weeks of the onset of the stroke. Beyond this time frame, rehabilitation has been found to be ineffective in producing significant results. Commencing treatment within the first month after stroke is of utmost importance, and according to reference [5], rehabilitation should not be performed beyond five months following the stroke.

To restore the condition and independence of stroke patients, physical therapy or rehabilitation is necessary. [6]. These therapy activities include: motor skill training for muscle strength and coordination [7], mobility exercises to relearn activity functions such as walking with assistive devices [8], exercises with resistance or with movement triggers [9], and Range of Motion exercises to improve joint ROM of stroke patients [10]. Some of these therapeutic exercise activities are implemented in the types of exercises and tasks given during therapy.

Currently, robotic technology is widely used in the world of stroke therapy. When compared to conventional therapy, Robot Therapy has the advantage of providing consistent rehabilitation that is intensive over a long period of time. [11], In addition, the Therapy Robot is able to quantitatively assess patient therapy data accurately to assist physiotherapists in evaluating patient conditions for each therapy. [12], [13], with the remote control, the Therapy Robot also has the advantage of operating the Therapy Robot without a physiotherapist or only with one physiotherapist as a controller where the physiotherapist and patient can maintain a distance from each other which prevents direct contact which can be one of the causes of transmission of the Covid-19 virus. In addition to producing good therapeutic exercises, the Therapy Robot also needs to produce a specific movement target in stroke, this precise and specific movement produces consistent repetitive exercises for patients with the same target every time. In the Therapy Robot there needs to be sensors that identify and record the patient's movements in real-time.

Generally, the evaluation of motor improvement in stroke patients is assessed using a clinical rating scale [14], some commonly used clinical assessments such as Fuegl-Meyer (FM)[15], Modified Asworth Scale (MAS) [16], and Functional Independence Measure (FIM)[17]. This clinical assessment is usually carried out at the beginning and at the end of the therapy program only, so that it cannot be seen the patient's motoric development at each time of therapy, besides that this clinical assessment seems objective based on the physiotherapist's ability to assess the patient's stroke condition because several assessors may produce different scores from a patient. Therefore, several recent studies have used kinematic and strength parameters recorded by Therapy Robots which are then used as an indicator that is proposed as an assessment of the patient's motor performance or commonly referred to as a robotic assessment. The purpose of this study is to review the development of robotic therapy for elbow and shoulder patients in terms of the assessment of kinematic parameters and types of exercises used to rehabilitate stroke patients.

In the next session, we introduced the methods used to review previous studies, such as the procedure for paper selection and explained the results of the selection. Afterwards, we provide a discussion of the different inclusion papers by surveying different kinematic parameters, measurement outcomes, validity of the measurements and exercises performed. Then, we point out the limitations and challenges and future research that needs to be done.

2. Materials and Methods

This review system followed the PRISMA rules [18]. We searched PubMed, Elsevier, Scopus, and IEEE-Xplore databases to find studies that used Kinematic Parameter assessment categorized in the International Classification of Functioning, Disability and Health (ICF) domain. We also summarized the types of exercise interventions performed in robotic therapy.

2.1 Stage 1, Search for Articles

Searching for articles about upper limb Robot Therapy for stroke patients which uses Kinematic Parameters as part of the evaluation of stroke patients. The articles searched were articles published between 2000 and 2022, the keywords to search for articles were "kinematic parameters", "robotic assessment for stroke" from the Journal Database. From this initial search, all titles and abstracts were read for screening. Then the journal was fully read to determine the final decision with the inclusion and exclusion criteria set. If there were similar research topics with the same author names, only the most recent studies were retrieved.

2.2 Stage 2, Inclusion and Exclusion Criteria

In this stage, the collected articles were selected based on several inclusion criteria: (i) Articles with a research focus on upper limb rehabilitation using therapeutic robots (end-effector or exoskeleton model robots); (ii) Research using at least 1 Kinematic Parameter as part of the assessment evaluation of stroke patients; (iii) Research subjects are humans with a minimum number of five patients. Exclusion criteria from this study were: (i) reviews, conference abstracts, and books; (ii) Article writing does not use English.

2.3 Stage 3, Sequencing Kinematic Parameters

Kinematic parameters of robotic exercise for stroke and the interventions performed and their effect on assessing the patient's motor development were collected from all the articles.

3. RESULTS

3.1 Journal Research

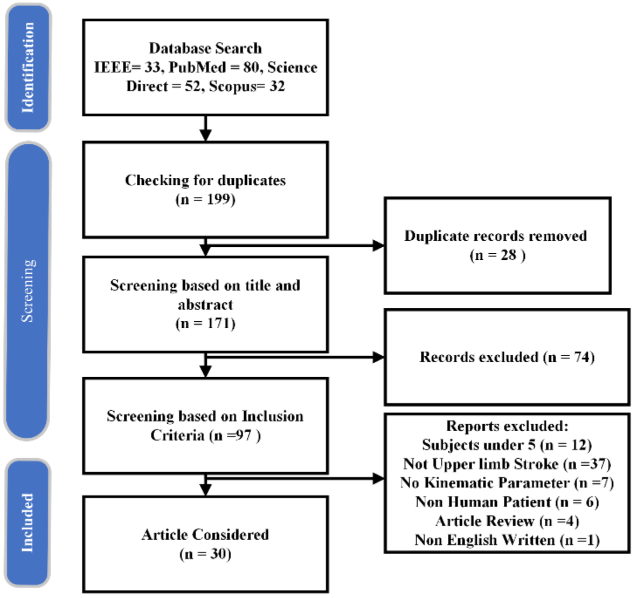

Fig. 1 Review flow chart based on the PRISMA guidelines

The literature search resulted in 199 articles from IEE, PubMed, Science Direct, and Scopus, after checking duplicates and excluding by inclusion and exclusion criteria a total 30 articles were included in this review (Fig. 1).

3.2 Upper Limb Kinematic Parameters

Based on the research of Balasubramanian et al [19], currently, the motion measures used in rehabilitation robots are categorized into 3 categories: Kinematic, this measure quantifies the spatial and quality of the patient's arm movements (movement deviation, time, and speed). Kinetic, these measures quantify force, work, energy consumption and power association in the patient's motor (force direction error, and amount of assistive support). Neuromechanical, measures viscoelastic properties or mechanical impedance (arm impedance). In the study Coderre et al present another classification of robotic measurements of Kinematic Parameters based on motor control theory: upper limb postural control which characterizes the patient's ability to keep his arm steady with respect to the midpoint.

The classification of kinematic parameters based on the International Classification Function of Disability (ICF) is divided into 4 domains namely Body Functions and Structures (BFS), Activities and Participation (AP), Enviromental Factors (EF), and Personal Factors (PF). BFS relates to basic human senses such as the function of seeing and other structures that exist and correlate with the eye, as well as the workings of the brain and its correlation with body movements. Damage to BFS may involve motion anomalies, defects, losses or other significant deviations in body structure. AP relates to the performance of tasks/actions by an individual and one's engagement in life situations. The limitations in AP have an impact on the difficulties one experiences in carrying out things and the problems one may face in engaging with one's life. EF and PF are contextual factors that are the background of a person's life and living. EF is related to the physical and social environment while PF is related to gender, lifestyle, age, body condition and others. [20].

MovAc, MovS, and nPS [21] are the example of a kinematic parameter in the "body functions and structures" domain that serves to analyze the movement error and smoothness of the patient's movement. TAT, Mdur, PD, MU [22]–[24] belong to the domain "activities and participation where this parameter evaluates the patient's exercise completion time and the number of exercise units performed. Fig. 2 was used to categorize each kinematic parameter.

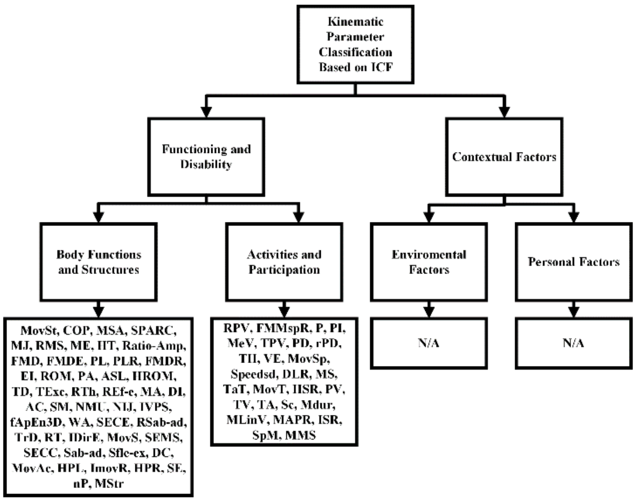

Fig. 2 ICF Categorization of Kinematic Parameters

3.3 Types of Shoulder Therapy Exercises

There are 3 categories of motor training movements used for Therapy Robot training: point to point, tracking, and manipulation [19]. Point to point movements have one starting point and several destination points to be addressed. One type of exercise in this model is

The purpose of VGR (Visually Guided Reaching) exercises is to perform independent reaching movements efficiently and precisely from a central point to eight peripheral points located evenly on a circle [13]. Bai L, et al [24] using the Drinking Test (DT), Bean Bag Test (BBT), and Nine Hole Peg Test (NHPT) exercises where these three exercises require the patient to move items from one point to another.

In the Tracking model [26], there is a single starting point and a single endpoint, and the patient moves their arm along the trajectory from the start point to the end point.

Manipulation task [27] movements manipulate the exercise using hand and finger movements. Trajectory Tracking (TT) is a motor training method which relies on an iterative approach of injected control to ensure the patient's movements are close to the intended model shape.

Table 1
Kinematic Parameters Used in Robot Upper Limb Rehabilitation (continued)

Robot	Study	Type of task	Kinematic Parameters		Clinical Outcome	n	Type Stroke	Results
KINARM	[28]	VGR	PS RT nRT IDirE IDisE	ISR SpM MMS PTR MS nMovEn	FMA SIAS MAS WMFT	56	CS	11 VGR parameters showed significant differences between paretic and non-paretic arms, 10 VGR parameters were significantly correlated with FMA, and 8 parameters were significantly correlated with SIAS, MAS, and WMFT.
	[29]	VGR	PS RT nRT IDirE IMovR HSR	nP MMS nMovEn MovT HPL MS	CMSA BSR	52	MS	9 parameters showed good reliability (ICC, r>0.7; P<0.05. nRT, nMovEn, and HPL were excluded from the analysis because they showed low reliability. Left-handed stroke patients showed significant associations between sensorimotor attributes and CMSAa (P<.05), while right-handed patients in addition to postural control and feed forward control also showed significant associations.
Xsens MTx	[30]	DT BBT NHPT	MovS TV TA		DAS MAS MoAS	5	FS	The MovS was assessed based on the number of movement units (NMU) and jerk scores (NJS). The TA exhibited a strong correlation with MAS at the elbow and wrist joints, whereas TV was significantly associated with MAS at the shoulder and hand.
NMES dan Pure robotic hand	[31]	Hold and release grasp	MA		FMA MAS ARAT FIM	30	CS	Compared to the pure robotic hand, the NMES group demonstrated significant enhancements in motor function and MAS score.
Virtual Reality Rehabilitation System	[22]	VR	MDur MLinV MovS		FMA FIM RPS MAS	122	MS	Virtual Reality (VR) can be integrated well for stroke therapy exercise programs, in this study, the main outcome is the Fuegl Meyer Assessment obtained results with an effect size of d = 0.54 where this value is large enough to detect clinical differences between experimental and control groups.

Table 1

Kinematic Parameters Used in Robot Upper Limb Rehabilitation (continued)

Robot	Study	Type of task	Kinematic Parameters		Clinical Outcome	n	Type Stroke	Results
InMotion Arm	[32]	VGR	MovT MeV MV SE nP	MAPR NPL RMS LP	-	61	MS	The test-retest reliability of the 9 kinematics parameters was indicated by p<0.05 values for Interclass Correlation Coefficient (ICC), Standard Error of Measurement (SEM) and Minimum Detectable Difference (MDD).
Armeo Spring	[23]	VGR	TaT MovT PV	HPR nP Sc	-	30	MS	The parameters TaT, MovT, HPR, nP and Sc have excellent reliability with ICC>= 0.75. Minimal Detectable Change (MDC) values between 42.6-102.8% indicate moderate reliability for all kinematic parameters.
InMotion 2.0	[33]	VGR	MovAc MS nP MovT		MBI MIuL	68	SS	nPs represents the smoothness value (lower nPs higher smoothness), almost all kinematic parameters showed significant intersession differences during 5/10 sessions, and thereafter there were no significant differences (Robot Therapy was seen to improve motor function especially at the beginning of the treatment session).
	[34]	VGR	MovAc MovSp nPS TaT		-	68	MS	The MovAc value decreased during the exercise, indicating the better movement accuracy of each patient, the MovSp value increased with each exercise and significantly increased after the 5th session. nPS indicates the smoothness of the movement of the patient's exercise. The group with more severe impairment consistently exhibited higher nPS of resultant velocity.
	[35]	VGR	DI VE	AC SM	FMA	22	SS	During the rehabilitation process all kinematic parameters improved. Based on this study it was found that the development of quantity of motion related to ROM, speed and smoothness parameters may precede the accuracy of motion.
	[36]	PtP	nP MV	Ratio-Amp Mdur	FMA MI MAS	12	SS-CS	While the MDur of each exercise decreased for both SS and CS patients (p<0.05), the smoothness of movement (nP) and MV increased significantly in both groups, and corresponded to an increase in the average speed of the patients.

Table 1

Kinematic Parameters Used in Robot Upper Limb Rehabilitation (continued)

Robot	Study	Type of task	Kinematic Parameters		Clinical Outcome	n	Type Stroke	Results
InMotion 2.0	[37]	DT	MovT MU TD		ARAT FMA	51	MS	There was a significant association of 31-36% change between ARAT and Kinematic measurements. The 3 kinematic parameters used demonstrated clinically meaningful improvement and were responsive measures to capture upper limb improvement within 3 months after stroke.
InMotion 3	[38]	VGR	MeV		FMA MAS	11	CS	Quantitative improvement occurred in the increase in ROM indicated by FMA, increased abduction movement, and increased extension movement obtained after therapeutic robot exercises even without changes in movement speed.
Robot-assissted Therapy	[39]	VGR	MovT TrD PV nP TPV	LDJ RSf-e RSab-ad REf-e RTh TExc	FMA WMFT MAL	10	CS	Upper panel shows low-moderate correlation (r<0.7) with clinical outcomes despite showing significant associations between some kinematic parameters and clinical outcomes. The lower panel displays a strong correlation between variations in kinematic parameters and clinical outcomes.
Optoelectronic ProReflex Motion Capture System	[24]	DT	PV PD rPD	TPV TD	-	13	CS	Elastic tape did not directly affect the spatiotemporal parameters of the tasks given for chronic stroke patients. Each elastic tape intervention group increased elbow extension, shoulder elevation. No changes in spatiotemporal parameters were observed from both groups during each exercise phase.
AMADEO	[40]	ST	Force-Flexion Force-Extension	HROM	FMA MAS	7	MS	After completing the training, Group A demonstrated a substantial reduction in Npeak amplitude in seven out of eight electrodes. Each patient had improvements in all three kinematic parameters.
Wrist and elbow-shoulder manipulator Robot	[41]	TT	MeV MovAc PI		FMA MSS MRC MP	16	CS	Both intervention groups showed improvement in the patient's motor impairment. Group 1 had significant improvement in wrist-extension ROM, Group 2 had significant improvement in strength and robotic parameters. The relationship between robotic and clinical measurements showed a moderate to significant relationship.

Table 1

Kinematic Parameters Used in Robot Upper Limb Rehabilitation (continued)

Robot	Study	Type of task	Kinematic Parameters		Clinical Outcome	n	Type Stroke	Results
UL-EX07	[42]	VGR	ROM PA TD ASL EI		FMA	15	CS	Both grades (conventional and proposed metrics) showed consistent improvement and no significant difference. Since the assistive mechanism must be both stable and secure, it is challenging to anticipate the patient's intent and determine the ideal level of assistive force to be applied to the patient.
ulRT	[43]	VGR	MovAc MeV nPV		MI	66	CS	Age is a significant prognostic negative factor and MovAc is a significant prognostic positive factor and can be suggested, as well as smoothness (nP in the direction of C) can be predictive of trajectory accuracy, this outcome shows an increase in motor recovery with a decrease in the number of Velocity Peak (nPV).
RGS	[44]	VR	WA DC P MS	MovS DLR TGDM	FMA CAHAI BI	98	MS	TGDM and DLR were highly correlated with all clinical assessment outcomes. All kinematic parameters showed constant Inter variable correlation results, MS showed high correlation with WA. The most relevant outcomes with FMA assessment were DLR and TGDM. DC also showed changes that were relevant to the clinical assessment changes.
Phantom Omni Haptic Device	[45]	VR, PtP	MovT MeV PV	TPV MovS	FMA ARAT	64	MS	Kinematic parameters explained slightly higher variation in FMA than ARAT. Kinematic parameters showed a stronger correlation to impairment than activity capacity assessment.
Oculus Version DK2, Optitrack	[26]	TT	RMSE Speedsd MJ IVPS fApEn3D		-	21	H	Except for IVPS (1D-2D) and fApEn3D (2D-3D), all kinematic parameters demonstrate a significant increase as the trajectory dimension increases. However, increasing time parameters (Speedsd, RMSE, and MJ) at higher dimensions result in a decline in accuracy, energy efficiency, and multijoint coordination, respectively.
IMU sensor System	[46]	TT	MT tPV MeV PV NMU	NIJ	FMA ARAT MBI	37	MS	MV had very strong correlations with FMA and ARAT. PV had significant correlations with all clinical assessments performed. Meanwhile MT, tPV, and NIJ did not show a good correlation with the Clinical Assessments.

Table 1

Kinematic Parameters Used in Robot Upper Limb Rehabilitation (continued)

Robot	Study	Type of task	Kinematic Parameters		Clinical Outcome	n	Type Stroke	Results
IMU Sensor System	[47]	RtG	SECE SEMS SECC	TDp SAbAd SFleEx EFIEx	FMA	26	CS	Therapeutic exercise showed significant effects on all kinematic parameters. Statistically, the most significantly correlated with FMA was curve efficiency.
KINARM	[48]	VGR, APMT OHT OHA	RT FMD FMDE MovT PL PLR ME, HT	SpM MMS FMMSpR FMDR PS TH MA	-	116	MS	TH, ME, HT, MovT are kinematic parameters with the highest nodes score. From the results it can be seen that OHT and OHA tasks produce good predictions of VGR and APMT with r>0.5 values. The proposed task sequence structure is OHA-OH-APMT-VGR, this structure is able to reduce robotic assessment time in patients with minimal motor impairment.
MIT-Manus Robot	[49]	VGR	PV MJ RMS		FM MP	208	MS	The robotic measurement scale was combined with Artificial Neural Network, the robotic measurement was demonstrated to have higher sensitivity in measuring patient recovery from day 7-90.
Electromagnetic Motion Device	[50]	RtG	SPARC		FMA ARAT	40	CS	SPARC showed a significant longitudinal association with FMA (P<0.001). The results suggest that patients who improve in movement smoothness will also produce improvements in motor impairment in the parallel.
ProReflex	[27]	VGR VR	MovS MovAc COP MSA	MeV PV RPV MovSt	-	15	MS	MovS increased during VGR practice and MovAc increased during VR practice, while MSA did not change between the beginning and end of practice.
Multi Sensor Robot	[51]	PtP TT	MStr		FMA BSR MI	9	H	Correlation between the mean coefficient of exercise and MStr, TT had a high correlation with the level of MStr, and had a moderate correlation with PtP.
Rehabilitation Robot	[52]	PtP	JM MAPR	Tent PS MovSp	FMA	31	MS & CS	All metric of movement smoothness show an in decreasing value that indicates an increase in smoothness movement, the highest correlation to the Fuegl Meyer Assessment is Jerk Metric (r = 0.48)

4. DISCUSSION

When evaluating upper limb movements in stroke patients, three kinematic parameters, namely motion accuracy, motion smoothness, and completion of exercise, are commonly employed. The primary motor cortex, premotor cortex, basal ganglia, and cerebellum are four brain regions responsible for motor planning and control in the human body. All four areas contribute to the initiation, planning, and execution of movements [53].

MovAc (Movement Accuracy) is a basic parameter commonly used to evaluate patient motor improvement in motion accuracy, where MovAc is calculated based on the accuracy of the patient's hand movements, the lower the value, the more precise the patient's movements will be with the trajectory provided. Goffredo M, et al [46] said that MovAc is a positive prognastic factor that can be suggested to evaluate patients. In the study [54] Equation 1 calculates MovAc using the X and Y coordinates of the data points (pxi and pyi) and the orthogonal projection points on the reference shape (Rxi and Ryi) associated with the analyzed shape. The variable 'n' represents the number of positions obtained during the exercise.

$$\sum_{i}^{n} = 1\frac{\sqrt{(Rxi - Pxi)^2 + (Ryi - Pyi)^2}}{n} \quad (1)$$

In measuring the smoothness of motion, there are five metrics, namely: Jerk Metric, Number of Peak Speeds, Speed Metric, Reaching Speed, dan Acceleration Metric [55]. While these five smoothness metrics can measure the smoothness of motion, Among these five metrics, the Jerk Metric offers a compelling explanation of the smoothness [52]. MovS (Movement Smoothness) using the Jerk Metric method is assessed from the jerk of the movement that occurs, there are several studies that calculate this parameter from the integration of jerks with equation 2, the smaller the S value, the smoother the movement produced by the patient during the therapy process. The smoothness of a patient's movement, which is indicative of their motor improvement, can potentially be predicted by MovS.

$$S = \sqrt{\frac{1}{2}\int jerk^2 dt * (\frac{duration^5}{length^2})} \quad (2)$$

In addition to the Jerk Metric, there are several studies that assess the correlation of smoothness of movement with the Number of Peak Speed Metric with clinical judgment. [28][56]. PS (Peak Speed) and nPS (number of Peak Speed) [21] This is assessed by analyzing the velocity peaks of the patient's upper limb movements. Fewer accelerations and decelerations during movement result in lower nPS values, indicating smoother movements. The nPS value is calculated by adding the resultant velocity peaks, which are obtained by using equation 3 to calculate the resultant velocity.

$$v_{xy}[k] = \sqrt{(v_x[k])^2 + (v_y[k])^2} \quad (3)$$

The speed of completing an exercise is also a parameter assessed from the evaluation of the patient's upper limb movements, when the primary motor cortex and basal ganglia of the brain are damaged, the movements of stroke patients will tend to be slower than those of healthy people. Movement Speed (MovSp) [34] MovSp is used to assess the patient's movement speed in completing the given exercise. The MovSp value can be calculated by the average value of the resultant velocity in the xy plane with equation 4.

$$MovSp = \frac{1}{N}\sum_{k=1}^{n}\sqrt{(v_x[k])^2 + (v_y[k])^2} \quad (4)$$

There are 4 standard evaluation criteria methods that can be used to evaluate an assessment parameter: [57] there are reliability, validity, responsiveness, and acceptability. [23], [29], [32] using the reliability method this method shows the extent to which the same results will be obtained on repeated measurements of the same system by the same person or different people. Reliability is generally measured by ICC, Standard Error of Measurement, and MDD. Koeppel, et al [32] showed 9 parameters (MovT, MovSp, MV, SE, nP, MAPR, NPL, NPL, and NPL) that are measured by the ICC, Standard Error of Measurement, and MDD, RMS, LP) has good reliability with ICC value > 0,75.

[13], [29], [30], [39], [46], [37] use the validity method by correlating standardized clinical assessments with the assessment system under study. The validity method indicates the extent to which the measure represents a conceptual domain. This criterion measures the extent to which the measured correlates to an existing standard. Chen Z, et al[46] showed that MeV produced very strong correlations with FMA (r=0.85, P<0.01) and ARAT (r=0.80, P<0.05), and PV also showed strong correlations with all its clinical assessments (r=0.55-0.81, P<0.01).

In the Trajectory Tracking exercise type, kinematic parameters that can be obtained to evaluate the patient's motor development such as MovSp, MovAc, MovS, while for the Point to Point exercise type there are parameters such as the patient's reaction to the displacement of the point to be achieved which is assessed by the kinematic parameters Reaction Time (RT) and no Reaction Time (nRT) [13].

VGR [27], [43], [49], [49]provides some information related to sensorimotor function such as the ability to stabilize the patient's arm with a central target that tells the patient's upper limb control position. This task provides information about the patient's ability to respond to peripheral visual targets, including the timing of the motion reflex. Additionally, the task can be divided into two distinct components: feed-forward control, which relates to the initiation of movement, and feedback control, which relates to corrective movement.

5. RECOMMENDATIONS FOR FUTURE RESEARCH

For selecting suitable outcome kinematic parameters to evaluate upper limb of stroke rehabilitation patients with linear tracking task we arrange three domains. First is accuration of patient’s movement which be evaluated by movement accuration (MovAc), the second is the smoothness of patient's movement which be evaluated by jerk metric, and number of peak speed (nPS), and the third is duration of finishing task which be evaluated by movement duration (MDur). However, at present there are no established criteria or guidelines for determining the most suitable kinematic measures for assessments. Some kinematic parameters which showed moderates correlations to the clinical assessment means that kinematic parameters can't stand alone to assess the progress of therapy programme of patients. By utilizing both clinical outcome measures and kinematic parameters, valuable insights can be gained not only regarding the patient's recovery progress, but also regarding their distinct movement patterns.

6. CONCLUSION AND STUDY LIMITATIONS

As of now, there are no established guidelines for determining the most suitable kinematic parameters to assess the improvement in patient motor function. Future research in the development of Robotic Therapy must begin with a fixed assessment scale to be able to consistently determine the severity of the patient's stroke and its development during the robotic therapy process carried out, it is hoped that the improvement in the value obtained in the assessment of kinematic parameters will have a positive impact on the patient's independence level. The assessment of kinematic parameters certainly cannot stand alone and still requires an existing clinical assessment, where this clinical assessment is used in assessing the patient's condition before and after therapy and kinematic parameters are used in assessing the patient's progress during the therapeutic exercise process. This study has some limitations, including the fact that the articles for review were selected using inclusion and exclusion criteria that may not have been ideal. Despite this, we included as many articles as possible and made the decision to exclude certain articles that met the initial criteria, but whose topic was already covered in other articles.

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Abbreviation

Task	Kinematic Parameter		Clinical Assessment	Status
VGR= Visually Guided Reaching	RPV= Relative time of Peak Velocity	P= Performance (%)	MP= Motor Power	H= Health
APMT = Arm Position Matching Task	MovSt = Movement Straightness	EI= Efficiency Index	CAHAI= Chedoke Arm and Hand Activity Inventory	CS= Chronic Stroke;
OHT= Object Hit Task	COP = Centre of Pressure Path	ROM= Range of Motion	MSS= Motor Status Score	FS= Focal Spasticity;
OHA= Object Hit and Avoid Task	MSA= Maximal Shoulder Angle	PA= Painted Area	MRC= Medical Research Council	MS= Moderate Stroke
TT= Trajectory Tracking	SPARC = Spectral Arc Length	ASL= Area around Straight Line	MP= Motor Power	PS= Post Stroke
VR= Virtual Reality	MJ =Mean Jerk	PI= Performance Index	MAL= Motor Activity Log	NI= Neuromotor Impairment
RtG= Reach to Grasp	RMS= Root Mean Square of Jerk	MeV= Mean Velocity	FMA= Fuegl Meyer Assessment;	SS= Subacute Stroke
PtP = Point to Point	ME = Median Error	HROM= Hand Range of Movement (%)	SIAS= Stroke Impairment Assessment Scale;	
DT= Drinking Task	HT= Hand Transition	TPV= Time to Peak Velocity	MAS= Modified Ashworth Scale;	
BBT = Bean Bag Test	Ratio-Amp = ratio between Average Longitudinal and Average tangential	TD= Trajectory Deviation	WMFT= Wolf Motor Function Test;	
NHPT = Nine Hole Peg Test	FMD= First Movement Distance	PD= Phase Duration	DAS= Disability Assessment Scale;	
ST= Shape Test	FMDE= First Movement Direction Error	rPD= relative Phase Duration	MoAS= Motor Assessment Scale;	
	PL =Path Length	TExc= Torso Excursion (cm)	ARAT= Action Research Arm Test;	
	PLR=Path Length Ratio	RTh= (Range Thorax) (degree)	MBI= Modified Barthel Index	
	FMMSpR= First Movement Maximum Speed Ratio	REf-e= Range Elbow Flexion/Extension (degree)	MIUL= Motricity Index paretic Upper Limb	
	FMDR= First Movement Distance Ratio	RSf-e= Range Shoulder Flexion/extension (degree)	FIM= Functional Independence Measure;	
	TH= Total Hits	RSab-ad= Range Shoulder abduction/Adduction (degree)	RPS= Reaching Performance Scale;	
	MA = Movement Area	TrD= Trunk Directness	CMSA= Chedoke-MCMaster Stroke Assessment Scale	
	DI = Distance Index	TPV= Time Peak Velocity (%)	BSR= Brunnstorm's Stages Recovery	
	VE = Velocity Index	MU= Movement Unit	MI= Motricity Index	
	AC = Accuracy Index	PS= posture speed (m/s)	EmNSA= Erasmus MC Modification of the Notingham Sensory Assessment	
	SM = Smoothness Index	RT = Reaction Time (s)		

NMU = Number of Movement Units	nRT= no Reaction Time
MovSp= Movement Speed	IDirE= Initial Direction Error
NIJ= Normalized Integrated Jerk	MStr = Muscle Strength
Speedsd =standard Deviation of speed	IDisE= Initial Distance Error (rad)
MJ= magnitude of Jerk	LP= Last Point of Movement (cm)
IVPS= Integration of the Speed Power Spectrum	MS= Max Speed (m/s)
fApEn3D= 3D Fuzzy Approximate Entropy	nMovEn= no Movement End
DLR= Difficulty Level Reached	MovS= Movement Smoothness
WA= Work Area (m2)	TaT= Task Time (s)
SECE = Shoulder Elbow Curve Efficiency	PV= Peak Velocity (cm/s)
SEMS= Shoulder Elbow Median Slope	HPR= Hand Path Ratio
SECC= Shoulder Elbow Correlation Coefficient	TV= Total Velocity (mm/s)
TDp= Trunk Displacement	TA= Total Acceleration (m/s^2)
Sab-ad= Shoulder Abduction - Adduction	Sc= Score (%)
Sfle-ex= Shoulder Flexion - Extension	MA= Muscle Activation
Efl-ex= Elbow Flexion - Extension	MDur= Movement Duration
DC= Distance Covered (m)	MLinV= Mean Linear Velocity
MovT= Movement Time (s)	SE= Smoothness Error (%)
NPL= Normalized Path Length (%)	nP= number of Velocity Peak (nb)
MovAc= Movement Accuracy	MAPR= MeanArrest Period Ratio (%)
HPL= Hand Path Length (m)	ISR= Initial Speed Ratio
HSR= Hand Speed Ratio	SpM= Speed Maxima
ImovR= Initial Movement Ratio	MMS= Min-Max Speed (m/s)
IoC= Index of Curvature	