

Kinematic Analysis on Reaching Activity for Hemiparetic Stroke Subjects Using Video Processing Method

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ABSTRACT

The purpose of the study was to analyse the trajectory and the kinematic variables (displacement, velocity, acceleration) of reaching activity for the upper limb part of hemiparetic stroke patient using video processing method. The analysis was conducted for three different categories which were recovery, half recovery and non-recovery. Six subjects were divided equally and they were asked to perform three trials for each reaching task, the trial was done while the subjects were sitting on a straight-back chair or on their wheel chair and all the test was conducted by a qualified physiotherapist. Video cameras were used to record the reaching movement in two dimensional perspective and from the video, the kinematics value was measured. The comparison analysis was done and evaluated based on the kinematics performance, reaching trajectory, maximum, mean value and the standard deviation for distance, velocity and acceleration value. The results of this study were consistence with those reported in the previous literature (Chang *et al.*, 2008).

INTRODUCTION

Human motion analysis has been one of the interesting fields in robotic applications, it has a wide range of application. Among of these application, biomedical area showed a promising prospect in the coming era. This was due to the baby boomers era during 40s and 60s (Jones, 2009) were entering their retirement phase and now become ageing population and various health problem starting to occurred within these population. Most of the health problem related to stroke, joint and muscle problem and it can affect their lifestyle performance to do a normal Activity for Daily Living (ADL) (Darin *et al.*, 2016).

Reaching was one of ADL task, difficulty to perform reaching was a significant post-stroke problem. It was found that 70% to 75% of survivors demonstrated limitations in reaching and a further 20% of survivors were not able to move the upper limb at all. Reaching was a typical functional arm movement and requires multi-joint coordination in completing activities of daily living (Chang *et al.*, 2008). Previous studies have examined the reaching kinematics of normal, Parkinson's disease and stroke subjects. These kinematic studies in reaching performance had found that subjects with movement disorders have increased movement duration, decreased velocity, increased segmentation and increased variability in path trajectory. In addition, subjects with movement disorder significantly show less smooth and continuous path trajectory when reaching to an object with higher accuracy constraints (Cheung *et al.*, 2009).

A study was conducted showed that alterations in muscle activation was present in hemiparetic subjects regardless of lesion location, the initial level of motor severity (Wagner *et al.*, 2007), or time since initial assessment of stroke. While muscle onset times were delayed in the hemiparetic group, the prime movers of the reaching task which were anterior deltoid and biceps brachii were activated prior to the start of the movement, to initiate the reach. In contrast, muscle onset times of the wrist extensors and flexors occurred after the start of movement at the acute time point. The delay in muscle

onset times for wrist extensors and flexors may reflect greater deficits in the neural control of the distal upper extremity musculature, where the influence of the corticospinal system was the greatest. Kinematic pattern analysis in previous studies had been done in various ways. Most studies used wearable inertial sensor, VICON 3D optical motion capture system and others either in healthy individual or stroke patient. Marker placement used for all device in previous study mostly had common anatomic locations which are index fingertip, distal ulnar head (wrist), lateral epicondyle (elbow), ipsilateral and contralateral acromion processes (shoulders), and sternal angle (Chang *et al.*, 2008).

There were many kinematics variables which can be utilized to reflect the characteristics of reaching. While reaching for an object, stroke patients with moderate motor impairment showed irregular paths profiles along with more movement corrections in the in reaching. A previous study found that there were significant correlations between reaching kinematics which is peak velocity, the number of movement unit and normalized jerk score of movement and level of motor impairments (Chang *et al.*, 2008). A study done by (Wagner *et al.*, 2007) reported that reaching the performance of the acute hemiparetic group was generally poor, such that the hemiparetic group had lower peak speeds, larger endpoint errors and less efficient movements compared to the healthy control group.

MATERIALS AND METHOD

The objective of the research was to develop a non contact technique to assess the stroke patient reaching activity, this was to reduce the treatment time for the stroke patient with a less painful method. For human ethic protocol, the test was approved by UKM research ethics committee PPI/11-JEP-2016-410

Materials

Kinematic data was measured from six stroke patient subjects age between 55 to 65 years old and their movement was captured as they performed the reaching activity using a GoPro video cameras. Subjects were divided into 3 groups, Group 1 was for stroke patient that were already recovered, Group 2 was for stroke patient that can moved their upper limb part by their own but not yet fully recovered (weak muscle) and for the Group 3 was for stroke patient that cannot move their upper limb part by their own but being supported by their non-affected part. Subjects were placed with an attachable five sensor (marker) at their dedicated upper limb joint. The subject demography data can be referred in Table 1.

Table 1 Demography data for reaching test subjects

Subject	Age	Sex	Duration of stroke (years)	Condition
001	55	F	3	Group 1:
002	58	F	2	Recovery
003	61	F	5	Group 2:
004	63	M	4	Half Recovery
005	65	M	6.5	Group 3:
006	63	F	4	Non Recovery

Protocols

Subjects were asked to perform a forward reaching task while seated in a straight-back chair or in their wheel chair. Their trunk will be stabilized to the back of a chair to minimize compensatory trunk movements, the shoulder was in approximately 0° flexion and extension and 0° of internal rotation and the elbow is in 75° to 90° flexion, with the wrist rested palm down, and the finger joints in slight flexion on the pillow.

The beginning, reaching and ending position part of the event were determined through the velocity measurement reading. The beginning of the activity was recorded when the velocity increased from 0ms^{-1} , the reaching was determined when the velocity was decreased to 0ms^{-1} and start to increased back, the end of the movement was determined when the velocity decreased to 0ms^{-1} . Phase definition for each movement can be referred in Table 2.

Table 2 Phase movement definition

Phase	Activity	Detect by
Rest	Hand position were	Velocity value will
Position	horizontal with the target	be zero
Move	Hand begin to move towards	Velocity value will
Forward	the target object	positively increased
Reaching	Hand will reach the target	Velocity value will
target	object and stop for a second	be zero/nearly zero
Move	From the target object hand	Velocity value will
Backward	will move back ward to rest	negatively
Rest Back	Hand position were	Velocity value will
	horizontal with the target	be zero
	object	

Minor modifications such as increased shoulder internal rotation on the start position were allowed for some subjects to minimize any positional discomfort. Subjects were then be instructed to reach forward and touched a cylinder target positioned 90% of arm's length directly in front of the affected and dominant shoulder at shoulder height.

Subjects were given one or two practice trials prior to familiarize themselves with the task and the instructions. Three trials of reaching movement were recorded, data collection was limited to three trials only due to the reason hemiparetic subjects can easily feel the fatigue and to prevent the subjects from having stress issue when performed

the task. The position of the marker on the subjects for the reaching activity was shown in Fig 1.



Fig 1 (a) Position of the wearable sensor (marker) and (b) reaching task activity

Instrumentation and Video Recording

Cylinder object size $20\text{cm} \times 5.5\text{cm}$ was used for the reaching as a target object, the cylinder was also used as a calibration reference (length measurement) for the reaching activity.

GoPro Video Camera was used to capture the motion of the subject performing the reaching action with camera setting of 60 frame per second (fps) to ensure the sufficient video motion data for the subject. Two video cameras were placed on the left and the right side between the subject position.

Quintic biomedical software was used to track linear velocities, accelerations and the angular rotations based on the markers track that were attached along the upper limb at scapula, shoulder, elbow, wrist and fingertip.

Data Analysis and Signal Processing

The two dimensional data values (X and Y axis for each marker) were filtered using three point moving average method for marker trace data smoothing. Since the trace of the marker was manually plotted based on video observation, it should be filtered to minimise the error by using simple and efficient method. The data were resampled using three point moving average method. (Limin Sun et al., 2016). The original tracking was marked by the red line and the filtered tracking were marked by the green line as shown in Fig 2.

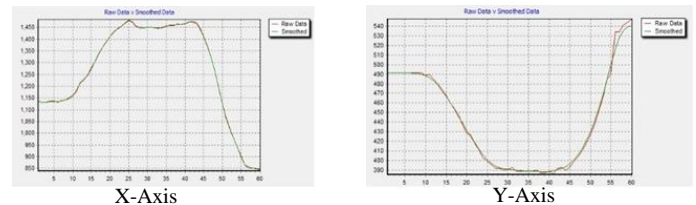


Fig 2 Data smoothing using moving average method

RESULTS AND DISCUSSION

At the end of the test, all the subjects managed to perform three reaching trials and complete the reaching movements. The result from reaching activity was analysed into three part which was movement Travelling trajectory, linear analysis and statistical analysis.

Movement Travelling Trajectory

The movement traveling trajectory pattern were plotted from X and Y axis point to point manually, using 60fps video image marker movement. The analysis was to compare the pattern between the stroke and normal side and also between each groups as on Fig 3.

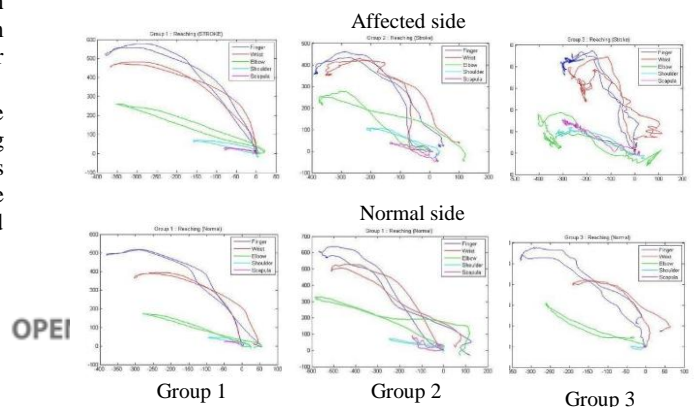
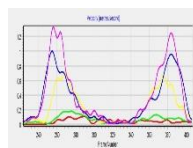


Fig 3 Reaching


trajectory pattern

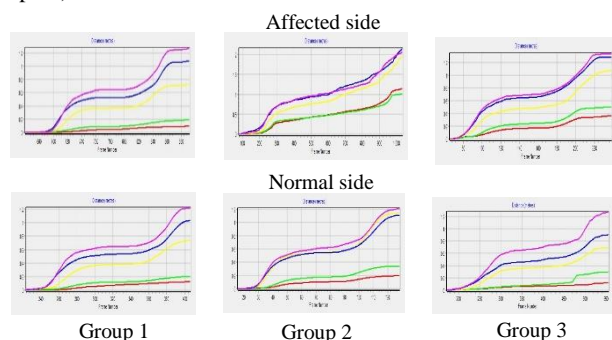
From the Group 1 trajectory travelling pattern, can be deduced that there was slightly small different pattern between the stroke side with the normal side pattern, on the normal side, reaching trajectory movement was shorter and more minimise. The trajectory for finger and the wrist on the affected subject travel in the similar pattern, this was suspected due to the affected finger were stiff, rigid and the subject cannot release their fingers when reached the cylinder object which makes the trajectory for wrist and finger travelled in similar way.

Group 2 showed a wider difference on trajectory pattern, the different between the affected and normal side become more obvious. The marker travelled in a longer way and an unstable movement, there was a ripple pattern can be seen on the tip of the graph which mean that the affected side has lack of muscle control once their hand reached the cylinder object. This also suspected due to their strength and flexibility of their muscle has been reduced after having a stroke.

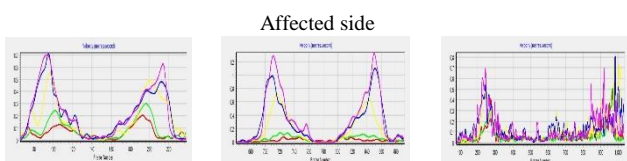
The different in the travel pattern in Group 3 were more obvious, the stroke travelled in a unstable condition from the begining and ripple pattern increased once the subjects reach the cylinder object. It means that the stroke patient does not have the ability to control smoothly the affected side using their own normal side upper limb. This was suspected due to the movement of their affected part were more stiff, smaller range of motion and have higher resistant.

Kinematic Analysis

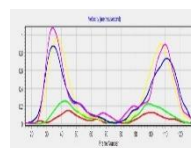
There were three kinematics variables being analysed through the reaching activity evaluation which were displacement, velocity and acceleration as showed in Fig 4, Fig 5 and Fig 6 respectively. The graph colour indicate the position of the marker which were indigo (finger), blue (wrist) yellow (elbow) green (shoulder) and red (scapula).


Fig 4 Displacement graph between each group for reaching activity

The total travel distance for the Group 1 was 4.81m (normal) and 3.78m (affected side), total travel distance for Group 2 was 5.89m (normal) and for 5.04m (affected) and total distance for the Group 3 was 12.2m (normal) and 5.27m (affected side), the total travelling distance was increased from the Group 1 to Group 2 and the Group 3. There were differences between the normal and affected side, total travel distance for normal side was lower than the stroke side, this was suspected due to the range of motion for the stroke side was smaller and the movement was limited due to the muscle stiffness.



Normal side



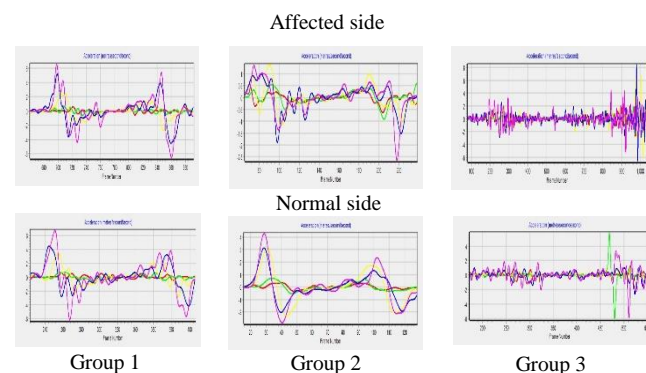
Group 1

Group 2

Group 3

Fig 5 Velocity graph between each group for reaching activity

The graph present the pattern of the velocity against time, the pattern was quite similar between the affected and the normal limb for the Group 1 and Group 2, but there a significant different in the velocity pattern aspect for the Group 3, there was more ripple peak on the affected part from the beginning of reaching activity, this was suspected due to the subject cannot control the movement by their own and the ripple part occurred to the affected part when it tried to against the movement supported from the normal side.


Fig 6 Acceleration graph between each group of reaching activity

The acceleration between the three groups showed a significant different between the pattern for the Group 2 and Group 3. The possible explanation for this results to be occurred was the acceleration normal side was smoother as the participant has a clear visual information when to accelerate and decelerate and performed the reaching movement process synchronised with the brain order, but for the affected side, there was a resistance came from the affected muscle and the acceleration and deceleration process was restricted physically. For the Group 1, both accelerations showed similar pattern for normal and affected side.

Statistical analysis was conducted as in the Table 3, three statistical variables which were maximum, means and standard deviation values were selected. For the travel distance, Group 1 showed shorter movement (min 0.36m/0.30m) and Group 3 showed longer movement (0.74m/0.31m). Group 1 also shows the larger variation of the data set (Stdv 0.16). The reason for the higher Stdv was the range of motion for Group 1 was larger than the other group. In term of velocity, Group 1 used the fastest route (min 0.3ms⁻¹/0.36ms⁻¹) with maximum velocity of 1.46ms⁻¹/1.88ms⁻¹, it represented the velocity control was better than the other group. The result for acceleration again was also better for Group 1 (min 0.01 ms⁻²/0.04 ms⁻²) with maximum acceleration of 8.70ms⁻²/8.59 ms⁻².

Table 3 Max, means and standard deviation for linear analysis

Kinematic		Group 1	Group 2	Group 3
Distance	Stroke			
	(m)			
	Max	1.42	1.34	2.16
	Min	0.36	0.47	0.74
	Stdv	0.16	0.13	0.13
Norm				

Velocity (ms ⁻¹)	Max	1.36	1.21	1.25
	Min	0.30	0.39	0.31
	Stdv	0.16	0.15	0.14
	Stroke			
	Max	1.46	0.71	0.5
	Min	0.30	0.15	0.28
Acceleration (ms ⁻²)	Stdv	0.18	0.24	0.00
	Norm			
	Max	1.88	1.08	0.87
	Min	0.36	0.194	0.01
	Stdv	0.22	0.12	0.07
	Stroke			
	Max	8.70	1.39	8.42
	Min	0.01	0.01	0.00
	Stdv	1.11	0.19	0.30
	Norm			
	Max	8.59	4.28	4.85
	Min	0.04	0.00	0.00
	Stdv	1.62	0.55	0.36

- Levin M.F., Michaelsen S.M., Cirstea C.M., & Roby-Brami A. 2010. Use of the trunk for reaching targets placed within and beyond the reach in adult hemiparesis. *Exp Brain Res.*;143(2): 171–80
- Jones, L. Y. 2009. Great Expectations: America and the Baby Boom Generation. Coward Mc Cann.
- Limin Sun1, Seppo P. Ahlfors, Hermann Hinrichs. 2016. Removing Cardiac Artefacts in Magnetoencephalography with Resampled Moving Average Subtraction Brain Topography, Volume 29, Issue 6, pp 783–790.
- Ma, Hui-Ing ScD; Lin, Keh-chung ScD; Hsieh, Fu-han PhD; Chen, Chia-ling PhD; Tang, Simon F. MD; Wu, Ching-yi ScD. 2017. Kinematic Manifestation of Arm-Trunk Performance during Symmetric Bilateral Reaching After Stroke: Within vs. Beyond Arms Length. *American Journal of Physical Medicine & Rehabilitation*: Volume 96 - Issue 3 - p 146–151.
- Massie C. L., Malcolm M. P., Greene D. P., & Browning R. C. 2012. Kinematic Motion Analysis and Muscle Activation Patterns of Continuous Reaching In Survivors of Stroke. *Journal of Motor Behaviour* 44(3):213–22.
- Messier S., Bourbonnais D., Desrosiers J., Roy Y. 2006. Kinematic analysis of upper limbs and trunk movement during bilateral movement after stroke. *Arch Phys Med Rehabilitation*;87(11):1463–70.
- Michaelsen S.M., Luta A., Roby-Brami A., Levin M.F. 2001. Effect of trunk restraint on the recovery of reaching movements in hemiparetic patients. *Stroke*;32(8):1875–83
- Subramanian, S. K., Yamanaka, J., Chilingaryan, G., & Levin, M. F. 2010. Validity of movement pattern kinematics as measures of arm motor impairment poststroke. *Stroke*, 41, 2303–2308.
- Wagner, J. M., Lang, C. E., Sahrman, S. a, Edwards, D. F., & Dromerick, A. W. 2007. Sensorimotor Impairments and the First Few Months of Recovery. *Physical Therapy*, 87(6), 751–76

CONCLUSION

The finding from the study showed that the efficiency rank of reaching movement performance was from Group 1 > Group 2 > Group 3, it was based on the efficient movement (shorter movement time), straight movement travelling pattern (less total displacement and travelling distance), smooth movement (velocity and acceleration,) stability (lower standard deviation for displacement and velocity) and optimisation movement (high angular value). The finding was agreed with the previous research (Chang *et al.* ,2008).

The result of the study proven can be used for real time stroke patient monitoring and as a base to improve the kinematic performance of for the stroke patient. It was a non contact method that provides a convenience monitoring and a less pain method for the stroke patient.

The study also showed the pattern differences between the normal movement and stroke affected in kinematic point of view that provided a better understanding of characteristic of the stroke patient reaching movement. For the further study, the experiment can be conducted simultaneously with the electromyogram (emg) sensor that can measure the strength of the muscle related to the kinematic variables.

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REFERENCES

- Chang, J.J., Yang, Y.S., Guo L.Y., Wu, W. L., & Su, F. C. 2008. Differences in Reaching Performance Between Normal Adults and Patients Post-Stroke : A Kinematic Analysis. *Journal of Medical and Biological Engineering*, 28(11):53-58.
- Chang, J.J., Yang, Y.S., Guo L.Y., Wu, W. L., & Su, F. C. 2008. The constructs of kinematic measures for reaching performance in stroke patients. *Journal of Medical Biol Eng.*;28(2):65–70.
- Cheung, V. C. K., Piron, L., Agostini, M., Silvoni, S., Turolla, A., & Bizzi, E. 2009. Stability of muscle synergies for voluntary actions after cortical stroke in humans. *Proceedings of the National Academy of Sciences of the United States of America*, 106(46), 19563–19568.
- Darin B Zahuranec, Lesli E Skolarus, Chunyang Feng, Vicki A Freedman and James F Burke. 2016. Are Limitations in Activities of Daily Living the Best Predictor of Well-Being After Stroke? *Stroke*. 47:A187, originally published February 16, 2016 stroke.ahajournals