

DEVELOPMENT AND USE OF A NEW TOOL FOR ASSESSING UPPER AND LOWER LIMB SYNERGIES IN PEOPLE WITH STROKE

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ABSTRACT

Background. While abnormal motor synergy is a major characteristic of stroke survivors, a major concern for rehabilitation clinicians, especially physiotherapists, deals with its assessment, evaluation, and meaningful intervention.

Objectives. This study was about the development and use of a new tool to measure accuracy in performance of functional motor synergies and activities of daily living in people with stroke.

Materials and methods. Thirteen stroke survivors comprising eight with left hemiplegia and five with right hemiplegia participated in this study. Each subject was instructed to perform a total of twenty six activities which involved touching designated point and stepping on designated quadrants. They were all assessed using a developed synergy assessment chart, on which was recorded the synergy assessment score and a developed synergy assessment board, on which was recorded the activity performance profile and abnormal synergy.

Results. This study showed that stroke survivors typically exhibit limitation of their motor, functional and daily living activities. Activity performance profile showed that 44.23% of participants exhibited abnormal synergy, 43.98% of activities could be performed in less than 1.5 seconds and 51.53% of activities could be performed in more than 1.5 seconds. Reliability test gave a value of 0.87 using the Cronbach's alpha. The new tool showed a good inter-item relationship when correlated with the Berg balance scale and Barthel Index ($p < 0.001$).

Conclusion. From the data gathered, the synergy assessment chart and board has a good reliability and inter-item correlation when compared with Berg balance scale and Barthel Index.

Keywords: stroke, synergy, assessment, tool

INTRODUCTION

Stroke is a common neurological disorder and a major cause of long-term disability, involving both motor and functional tasks (1). The disease is expected to increase in low and middle-income countries like Nigeria (1). It has been asserted that common upper extremity impairment after stroke includes: paresis, loss of fractionated movement, abnormal muscle tone and/or changes in somatosensation (2). Gerdienke *et al.* (3) further explained that this reduction in ability to coordinate movement, among others, can be expressed as an involuntary coupling of movements (3). These researchers also distinguished two patterns of coupling to describe the motor behavior of stroke survivors: a flexion pattern and an extension pattern

(3). For the upper extremity, the flexion pattern includes shoulder abduction, shoulder external rotation, elbow flexion and forearm supination, while the extension pattern comprises shoulder adduction, shoulder internal rotation, elbow extension and forearm pronation. This coupling of muscles, also referred to as synergy, to perform a motor or functional task is of utmost interest in the rehabilitation of people disabled by stroke (3). Assessment and evaluation of synergies following stroke have shown that some muscle groups outside the known synergy are difficult to rehabilitate (4). Beer *et al.* (5) asserted that in isometric contractions of chronic stroke survivors, the generation of shoulder abduction torques is coupled to simultaneous generation of elbow flexion torques: the higher the shoulder abduction torque, the more elbow flexion

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is generated (6). When extending this research to dynamic situations, they found limitations in elbow extension during reaching without arm support when the arm has to be lifted actively at shoulder height, since active shoulder abduction provoked simultaneous elbow flexion torques (5). Various outcome measures can be used in the assessment of muscle synergy. These outcome measures include: electromyography and neuro-rehabilitation robot (7). These outcome measures are cumbersome to administer, expensive and usually not within easy reach of a physiotherapist. Urrea *et al.* (8) asserted that current assessment scale do not take patient's neuromuscular state and synergy into consideration. Since the motor synergy is so vital to motor and functional performance, the need for a useful tool to assess it has become imperative. This study therefore is aimed at developing a new tool for assessing upper limb and lower limb synergy among stroke survivors.

MATERIALS AND METHODS

The study involved 13 stroke survivors (both male and female) with at least 3 months duration of stroke (DOS) who were receiving treatment at the Physiotherapy Department of the Lagos University Teaching Hospital (LUTH), Idi-Araba, Lagos. This study was designed to develop and use a new tool to assess upper limb and lower limb muscle synergies among stroke survivors. Stroke survivors with the following criteria were included into the study: intact cognition, intact vision, literate, Berg Balance Scale score greater or equal to forty one, Barthel index score greater than or equal to 50, and tolerable shoulder pain. The participants were selected using sample of convenience. Prior to the study ethical clearance was obtained from the Research and Ethics Committee of LUTH.

Each participant was asked to perform specific movement pattern using the synergy assessment board for upper limb, SAB-U (Fig. 1) and synergy assessment board for lower limb, SAB-L (Fig. 2), values were recorded on the synergy assessment chart for upper limb, SAC-U and lower limb, SAC-L respectively. The participant was asked to perform each movement pattern twice (i.e. touching each quadrants and placing the foot one each

quadrant). The time T_1 and T_2 (in seconds) was taken and the mean time (T_M) was calculated. As the participant performed each action, the movement was observed and crossed checked for the expected movement used on the synergy assessment chart. Abnormal synergies were noted and documented. Other information collected included the age of the participant, duration of stroke (DOS) and side of affectation. Duration of stroke (in months) was given as the period from the onset of the stroke to when the tool was administered.

The recordings of events on the boards had 3 domains. The first domain assessed achievability, the second domain assessed mean time to perform activity and the third domain assessed abnormal synergy. The sum of score for achievability was used as the synergy assessment score (SAS).

Achievability was determined from the mean time. When a participant was able to perform the activity in less than 1.5 seconds, a score of 2 was given. When a participant performed the activity in more than 1.5 seconds, a score of 1 was given. When a participant could not perform the activity, a score of 0 was given. Abnormal synergy was also assessed. This was scored based on observation and cross referencing with the normal synergy on the synergy assessment chart.

Results obtained were sorted out into 3 categories. These categories consisted of:

- Group 1 – These results included all participants regardless of what hemisphere was affected
- Group 2 – These results included of all participants that had left hemiplegia.
- Group 3 – These results included all participants that had right hemiplegia.

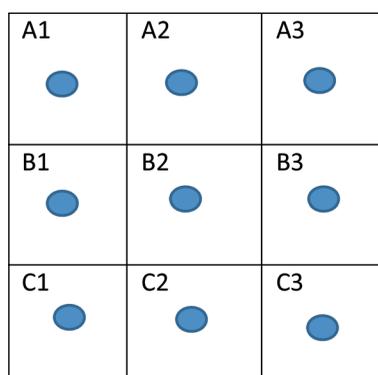


FIGURE 1. Picture showing the SAB-U

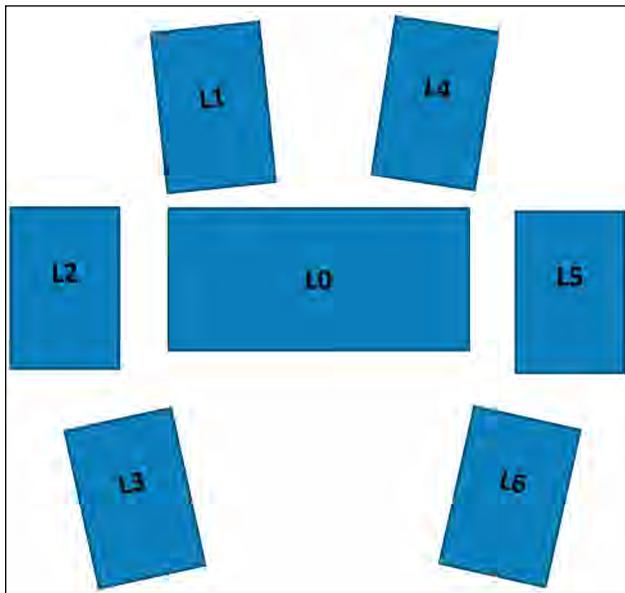


FIGURE 2. Picture showing the SAB-L

Each participant was expected to perform a total activity of 9 activities for the left upper limb (quadrant 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 3C); 9 activities for the right upper limb (quadrant 1A, 1B, 1C, 2A, 2B, 2C, 3A, 3B, 3C); 4 activities for the left lower limb (quadrant L1, L2, L3, L4); and 4 activities for right lower limb (quadrant L4, L5, L6, L1). A total of 26 activities were expected for each participant.

The lower limb was assessed first with the use of SAB-L. The participant was asked to stand on quadrant 0. Once the participant stood comfortably, with both legs within the quadrant 0, instructions were given to the participant to place limb of appropriate quadrant. The time taken to complete each action (i.e. place each limb from quadrant 0 to required quadrant) was record.

The upper limb was assessed using the SAB-U. The length of the participant upper limb was taken, from the acromion to the middle finger. The length in meters was taken and two-third of this length was used as the distance of participant to SAB-U. This was done due to variation in the upper limb length of each participant. The participant was asked to stand at the calculated distance away from SAB-U. The lower border of SAB-U was placed such that it lies at the same level with the sternal notch. This was done due to the variation in the height of individual participant. The midpoint of each quadrant was designated. The participant was instructed to touch the midpoint of each quadrant beginning with 1A and ending at 3C.

All participants were asked to perform each action twice for both upper limb and lower limb. The time T_1 and T_2 was taken and the mean time T_M was calculated. T_M was calculated. As the participant performs each action, the movement was observed and crossed checked the expected movement used the synergy assessment chart. Abnormal synergy was noted and documented.

The highest score possible for each upper limb is 18 (a total of 36 for the upper limb) while the highest score possible for each lower limb is 8 (a total of 16 for the lower limb). The highest total score possible is 52. Obtained values were recorded on a synergy assessment chart (SAC).

This tool can be administered in a time range of 10-15 minutes.

The data were analysed using the Statistical Package for Social Sciences (SPSS), version 21. Descriptive and frequency statistics were obtained for the variables. The Cronbach's alpha was calculated to determine the inter-item correlation between BBS, BIADL and SAS. A P value of < 0.01 was considered statistically significant.

RESULTS

GROUP 1

Results obtained showed a mean age of 50 ± 13.45 , BIADL 86.62 ± 9.46 , BBS 45.38 ± 0.51 , MMSE 28.69 ± 5.39 , SAS 37.85 ± 7.61 and DOS 5.62. Table 1 shows the inter-item correlation between the BIADL, BBS and SAS. This shows that there is no significant difference between the BIADL, BBS and SAS since $p < 0.001$. Table 3 shows a Cronbach's alpha of 0.87, which indicates a high level of internal consistency of the new tool.

TABLE 1. Inter-Item Correlation Matrix

	BIADL	BBS	SAS
BIADL	1.00	0.74*	0.65*
BBS	0.74*	1.00	0.66*
SAC	0.65*	0.66*	1.00

*Correlation is significant at the level $p < 0.001$

Achievability of performance of activities:

The obtained results showed that 4.48% of the 26 activities expected to be performed were not achievable. An average of 43.98% of activities (i.e. touching specific point on SAB-U and placing the

foot on specific point on SAB-L) was achievable but in more than 1.5 seconds. Only 51.53% of the 26 activities expected were achieved under 1.5 seconds (Table 4 and 5).

Abnormal synergy: From the results obtained it can be concluded that 44.23% of all participants had abnormal synergy present on either the upper limb or lower limb or both. This was calculated by computing the average of all percentages of abnormal synergy (Table 6 and 7).

TABLE 2. Gender and side of affection of the participants in Group 1

	Frequency	Percentage
Sex		
Male	9	69.2
Female	4	30.8
Total	13	100.0
Side of affection		
Left Hemisphere	5	38.5
Right Hemisphere	8	61.5
Total	13	100.0

TABLE 3. Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Bases on Standardized Items	N of Items
0.84	0.87	3

TABLE 4. Achievability to perform task with the upper limb for Group 1

Achievability	Quadrants																																																					
	1A						1B						1C						2A						2B						2C						3A						3B						3C					
	n	%	N	%	n	%	N	%	N	%	n	%	N	%	N	%	n	%	N	%	n	%	N	%	n	%	N	%	n	%	N	%	n	%	N	%																		
0	2	15.4	2	15.40	2	15.4	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7																				
1	8	61.5	8	61.50	8	61.5	8	61.5	6	46.2	5	38.5	6	46.	4	30.8	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5																				
2	3	23.1	3	23.10	3	23.1	4	30.8	6	46.2	7	53.8	6	46.2	8	61.5	7	53.5																																				
RUL																																																						
	1A						1B						1C						2A						2B						2C						3A						3B						3C					
	n	%	N	%	n	%	N	%	N	%	n	%	N	%	N	%	n	%	N	%	n	%	N	%	n	%	N	%	n	%	N	%	n	%																				
0	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7	1	7.7																						
1	5	38.5	3	23.1	4	30.8	3	23.1	4	30.8	4	30.8	4	30.8	3	23.1	2	15.4	5	38.5																																		
2	7	53.8	9	69.2	8	61.5	9	69.2	8	61.5	8	61.5	9	69.2	10	76.9	7	53.8																																				

Total number of participants = 13

KEY: LUL: Left lower limb, RUL: Right lower limb, RLL: Right lower limb, LLL: Left lower limb

GROUP 2

Results obtained are as follows: Mean age 50 ±12.05, BIADL 88.75±9.16, BBS 44.75±4.13, MMSE 29.25±1.75, SAS 37.63±7.1 and DOS 6.75.

Achievability of performance of activities: The degree of achievability for both the upper limb

TABLE 5. Achievability to perform task with the lower limb for Group 1

Achievability	Quadrants															
	L1				L2				L3				L4			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
1	8	61.5	6	46.2	8	61.5	9	69.2								
2	5	38.5	7	53.8	5	38.5	4	30.8								
RLL																
	L4		L5		L6		L1									
	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
0	0	0	0	0	0	0	0	0	0	0	0	0	0			
1	5	38.5	4	30.8	4	30.8	7	53.8								
2	8	61.5	9	69.2	9	69.2	6	46.2								

Total number of participant = 13

TABLE 6. Abnormal synergy observed when performing task with the lower limb for Group 1

Achievability	Quadrants															
	L1				L2				L3				L4			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Yes	8	61.5	8	61.5	8	61.5	8	61.5								
No	5	38.5	5	38.5	5	38.5	5	38.5								
RLL																
	L4		L5		L6		L1									
	n	%	n	%	n	%	n	%	n	%	n	%	n	%		
Yes	7	53.8	7	53.8	7	53.8	7	53.8								
No	6	46.2	6	46.2	6	46.2	6	46.2								

and lower limb (Table 8 and 9) showed that, 4.17% of the 26 activities expected to be performed were not achievable (score 0). An average of 44.67% of activities was achievable but in less than 1.5 seconds (score 1). Only 51.24% of the 26 activities expected were achieved less than 1.5 seconds (score 2).

TABLE 7. Abnormal synergy observed when performing task with the upper limb for Group 1

Achievability		Quadrants																	
LUL																			
		1A		1B		1C		2A		2B		2C		3A		3B		3C	
		N	%	N	%	n	%	N	%	n	%	N	%	n	%	n	%	n	%
Yes		5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5	5	38.5
No		8	61.5	8	61.5	8	61.5	8	61.5	8	61.5	8	61.5	8	61.5	8	61.5	8	61.5
RUL																			
Yes		3	23.1	3	23.1	3	23.1	3	23.1	3	23.1	3	23.1	3	23.1	3	23.1	3	23.1
No		10	76.9	10	76.9	10	76.9	10	76.9	10	76.9	10	76.9	10	76.9	10	76.9	10	76.9

Abnormal synergy: Results obtained showed that at 46.88% of all participants in Group 2 had abnormal synergy present on either the upper limb

or lower limb or both (Table 10 and 11). This was calculated by computing the average of all percentages of abnormal synergy.

TABLE 8. Achievability when performing task with the upper limb for Group 2

Achievability		Quadrants																	
LUL																			
		1A		1B		1C		2A		2B		2C		3A		3B		3C	
		N	%	n	%	N	%	n	%	N	%	n	%	n	%	n	%	N	%
0		2	25.0	2	25	2	25	1	12.5	1	12.5	1	12.5	1	12.5	1	12.5	1	12.5
1		5	62.5	6	75	6	75	6	75	5	62.5	4	50.0	5	62.5	4	50.0	4	50.1
2		1	12.5	0	0	0	0	1	12.5	2	25.5	3	37.5	2	25.0	3	37.5	3	37.5
RUL																			
		1A		1B		1C		2A		2B		2C		3A		3B		3C	
		N	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%	N	%
0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1		2	25.0	1	12.5	2	25.0	2	25.0	3	37.5	2	25	1	12.5	1	12.5	2	25
2		6	75.0	7	87.5	6	75.0	6	75.0	5	62.5	6	75.0	7	87.5	7	87.5	6	75
Total number of participant = 8																			

TABLE 9. Achievability when performing task with the lower limb for Group 2

Achievability									
LLL									
		L1		L2		L3		L4	
		N	%	N	%	N	%	n	%
0		0	0	0	0	0	0	0	0
1		5	62.5	4	50.0	5	62.5	6	75
2		3	37.5	4	50.0	3	37.5	2	25
RLL									
		L4		L5		L6		L6	
		n	%	N	%	N	%	n	%
0		0	0	0	0	0	0	0	0
1		2	25	1	12.5	3	37.5	4	50
2		6	75	7	87.5	5	62.5	4	50
Total number of participant = 8									

TABLE 10. Abnormal synergy observed when performing task with the lower limb for Group 2

Achievability		Quadrants							
LLL									
		L1		L2		L3		L4	
		N	%	n	%	n	%	n	%
Yes		7	87.5	7	87.5	7	87.5	7	87.5
No		1	12.5	1	12.5	1	12.5	1	12.5
RLL									
		L4		L5		L6		L11	
		N	%	n	%	n	%	n	%
Yes		4	50.0	4	50.0	4	50.0	4	50.0
No		4	50.0	4	50.0	4	50.0	4	50.0
Total number of participant = 8									

TABLE 11. Abnormal synergy observed when performing task with upper limb for Group 2

Achievability	Quadrant																	
LUL																		
	1A		1B		1C		2A		2B		2C		3A		3B		3C	
	N	%	n	%	n	%	n	%	n	%	n	%	N	%	n	%	n	%
Yes	4	50	4	50	4	50	4	50	4	50	4	50	4	50	4	50	4	50
No	4	50	4	50	4	50	4	50	4	50	4	50	4	50	4	50	4	50
RUL																		
Yes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No	8	100	8	100	8	100	8	100	8	100	8	100	8	100	8	100	8	100
Total number of participant = 8																		

TABLE 12. Achievability when performing task with the upper limb for Group3

Achievability	Quadrants																	
LUL																		
	1A		1B		1C		2A		2B		2C		3A		3B		3C	
	n	%	n	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	3	60.0	2	40.0	2	40.0	2	40	1	20.0	1	20.0	1	20	0	0	1	20.0
2	2	40.0	3	60.0	3	40.0	3	40.0	4	80.0	4	80.0	4	80.0	5	100	4	80.0
RUL																		
	1A		1B		1C		2A		2B		2C		3A		3B		3C	
	n	%	n	%	n	%	n	%	n	%	N	%	n	%	n	%	n	%
0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0
1	3	60.0	3	60.0	3	60.0	3	60.0	3	60.0	3	60.0	3	60.0	3	60.0	3	60.0
2	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0	1	20.0
Total number of participant = 5																		

GROUP 3

Results showed a Mean age of 50 ±11.00, BI-ADL 91 ±10.84, BBS 46.40 ±7.44, MMSE 27.80 ±3.90, SAS 38.20 ±8.96 and DOS 3.80.

Achievability of performance of activities: The degree of achievability for both the upper limb and lower limb (Table 12 and 13) showed that, 5% of the 26 activities expected to be performed were not achievable. An average of 48.48% of activities were achievable but in less than 1.5 seconds. Only 46.52% of the 26 activities expected were achieved in less than 1.5 seconds. The above overall achievability was calculated by computing the mean value of all activities with score 0, 1 and 2 respectively.

Abnormal synergy: The results obtained showed that 40% of all participants in Group 3 had abnormal synergy present on either the upper limb or lower limb or both. This was calculated by com-

puting the average of all percentages of abnormal synergy (Table 14 and 15).

TABLE 13. Achievability when performing task with the lower limb for Group3

Achievability	Quadrants							
LLL								
	L1		L2		L3		L4	
	n	%	n	%	n	%	n	%
0	0	0	0	0	0	0	0	0
1	3	60.0	2	40.0	3	60.0	3	60.0
2	2	40.0	3	60.0	2	40.0	2	60.0
RLL								
	L4		L5		L6		L1	
	n	%	n	%	n	%	n	%
0	0	0	0	0	0	0	0	0
1	3	60.0	3	60.0	1	20.0	3	60.0
2	2	40.0	2	40.0	4	80.0	2	40.0
Total number of participant = 5								

TABLE 14. Abnormal synergy observed when performing task with the lower limb for Group 3

Achievability	Quadrants							
LLL								
	L1		L2		L3		L4	
	n	%	n	%	n	%	n	%
Yes	1	20.0	1	20.0	1	20.0	2	40.0
No	4	80.0	4	80.0	4	80.0	3	60.0
RLL								
	L4		L5		L6		L1	
	n	%	n	%	n	%	n	%
Yes	3	60.0	3	60.0	3	60.0	3	60.0
No	2	40.0	2	40.0	2	40.0	2	40.0
Total number of participants = 5								

TABLE 15. Abnormal synergy observed when performing task for Group 3

Achievability	Quadrants																	
LUL																		
	1A		1B		1C		2A		2B		2C		3A		3B		3C	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Yes	1	20	1	20	1	20	1	20	1	20	1	20	1	20	1	20	1	20
No	4	80	4	80	4	80	4	80	4	80	4	80	4	80	4	80	4	80
RUL																		
Yes	3	60	3	60	3	60	3	60	3	60	3	60	3	60	3	60	3	60
No	2	40	2	40	2	40	2	40	2	40	2	40	2	40	2	40	2	40
Total number of participants = 5																		

DISCUSSION

The research was targeted at using a new tool for assessing upper limb and lower limb synergy among stroke survivors. Emergent of abnormal muscle synergy is a common clinical presentation among stroke survivors and it is pertinent for as assessment tool in this regard. From the result obtained, it was observed that abnormal synergy is a limitation in functional ability of hemiparetic patients. This is in agreement with Kaoru and Koji (9), who asserted that the abnormal synergy seen in patients after stroke is considered to limit the ability of these patients. The results obtained showed that 44.23% of all participants had abnormal synergy either in the lower limb or upper limb after mean duration of 5.62 months. In the upper limbs, the abnormal synergies include flexor synergy (shoulder abduction, elbow flexion, forearm supination) and extension synergy (shoulder adduction, elbow extension, and forearm pronation) as asserted by Ellis *et al.* (10).

Results obtained also showed that the lower limb showed better recover when compared with the upper limb as all activities was achievable with the lower limb. This is in agreement with Kyoung

et al. (11), who asserted that in comparison with the lower limb and trunk control, the upper limb showed less recovery.

According to Pamela *et al.*, (12) if recovery is defined at the disability level (Barthel > 90), the majority 57.3% of stroke survivors experience a full recovery. Although individual recovery patterns and outcome differ between patients, several prognostic studies have shown that outcome at 3 or 6 months is highly predictable for upper (13) and lower limb (14) as well as basic activities of daily living (ADLs) in general (15,16). Almost all participants showed a certain degree of spontaneous neurological recover (17). This agrees with the finding as most participants (about 44.67%) could perform the expected activities in more than 1.5 seconds while 51.24% could perform the required activities in less than 1.5 seconds. Though 4.48% of activities couldn't be achieved. From results obtained, a mean BIADL score of 86.62% was obtained. This shows a good functionality of participant 5.62 months post-stroke. Abnormal synergy exhibited by participants was in line with documented literatures.

The Cronbach's alpha was calculated (and the value 0.84) using SPSS version 21, and the ob-

tained result showed that the new tool is internally consistent and reliable. The new tool also showed good correlation with BBS and BIADL using the inter-item correlation matrix. This tool may serve as an alternative tool to assess balance and activities of daily living but should be subjected for further studies.

CONCLUSION

The synergy assessment chart and board was developed to assess abnormal synergy in the upper

limb and lower limb. It creates an alternative to assessing synergy pattern among stroke survivors. With results obtained from analysis the new tool showed good reliability.

When correlated with standardized tools – the Berg balance scale and Barthel index of activity of daily living, it showed that there was no significant difference between the synergy assessment scale, the Berg balance scale and the Barthel index of activity of daily living scale. It can be assumed that the SAC and SAB can be used to assess activity of daily living and balance of stroke survivors.

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