The relationship between weight bearing asymmetry after stroke and functional standing balance

ChengetanaiS[1], Tadyanemhandu C[2], Chibhabha F[3], Kaseke F[2]

[1]Department of Anatomyand Physiology, National University of Science and Technology
[2]Department of Rehabilitation, College of Health Sciences, University of Zimbabwe
[3]Department of Anatomy, Midlands State University

***Abstract*- Background:** Stroke can cause damage to the motor and sensory pathways or affect their central integration leading to disorders of balance, posture and control of movement. Stroke patients suffer from various balance impairments and tend to bear more weight in the non-paretic leg. The aim of the study was to determine if the weight bearing asymmetry of stroke patients in standing is related to their ability to maintain balance when performing functional activities in standing.

Methods: Twenty stroke patients participated in the study. Two bathroom scales were used to record the total body weight of each patient as well as the weight transmitted through each lower limb in standing. Static and dynamic balance was assessed in patients Patients' performances were rated according to the scoring system of the functional standing balance scale.

Results: 95% of the patients carried more weight on the non-affected leg. The non-affected leg carried on average 60% of the total body weight as opposed to 40% carried by the paretic limb. The average percentage difference between the limbs was 20%, the highest recorded difference being 42%. All patients were able to maintain the bilateral upright stance with feet 20cm apart but only 4 (20%) managed to stand on the affected limb in the unilateral stance for a time period of more than 5 seconds. Thirteen (65%) managed to stand on the non- affected leg for more than 5 seconds. Patients experienced difficulty executing the functional activities that required shifting of weight to the paretic leg. Patients that had a greater weight bearing asymmetry scored lower and those that had suffered a prior stroke performed poorly as compared to first time patients.

Conclusion: Patients experienced increasing difficulty in maintaining balance as the base of support was decreased. Patients showed increased postural instability in performing the functional activities that involved movement, especially when the body weight had to be shifted to the paretic limb. Patients should practice weight bearing symmetry activities as well as task specific exercises in order to learn how to maintain balance during those activities.

***Index Terms*-** Functional standing balance scale; Standing balance; Stroke; Weight bearing asymmetry

I. INTRODUCTION

Stroke is a significant source of disability in the adult population including that of the developing countries (Matenga., 1997; Aruin*et al.,* 2000; Tyson *et al.,* 2006). It can cause damage to the motor and sensory pathways or affect their central integration leading to disorders of balance, posture and control of movement (Sackley*et al.,* 1992; Laufer*et al.,* 2003; Mishra and Chitra., 2015). The assessment of balance is an essential part of the examination of stroke patients because of the various balance impairments that are experienced after stroke (Pyoria*et al.,* 2004; Kamphuis*et al.,* 2013). Arguably, the most easily observed and measurable change in stroke patients is their tendency in the upright stance to bear more weight in the non-affected leg (Dettmann*et al.,* 1997; Mishra and Chitra., 2015). Weight bearing asymmetry has been linked to impaired motor function and the standing balance problems of stroke patients (Bohannon and Waldron., 1991; Laufer et al., 2003;Pyoria*et al.,* 2004). Impaired motor function may be as a result of muscle weakness or abnormal tone causing difficulty in muscle use and leading to increases in postural sway and thus decrease in balance during movement leading to an increased risk of falling (Laufer*et al.,* 2003; Pyoria*et al.,* 2004; Chitra and Mishra., 2014). The aim of physiotherapy post-stroke should therefore be to promote functional recovery of the affected side by re-educating patients to regain independence in the execution of functional tasks (Lennon and Hastings., 1996). Increased use will increase the muscle strength of the affected limbs, improve standing symmetry and balance and facilitate the relearning of motor skills (Gunes*et al.,* 2001; Olaniyi and Akosile., 2012). Patients with balance problems take a much longer time to reach the same level of function than do stroke patients without balance problems (Pyoria*et al.,* 2004). An understanding of the relationship between weight distribution in standing and standing balance when performing functional activities allows the therapist to make an informed decision in formulating an appropriate treatment plan for the patient, since balance status is considered as one of the determinants for the prediction of post-stroke functional outcomes (Inouye 2001). This study investigated whether the weight bearing asymmetry of stroke patients in standing was related to their ability to maintain balance when performing functional activities in standing.

II. METHODS

Study design and setting

This was a descriptive cross-sectional study carried out using the facilities of the rehabilitation departments at Chitungwiza and Parirenyatwa Central Hospital and St Giles Medical Rehabilitation Center in Harare, Zimbabwe. Data was collected over a period of three months.

Participant sampling

The participants for this study were sampled from willing patients receiving inpatient or outpatient physiotherapy services at the mentioned rehabilitation units. A sample of convenience was used consisting of the first 20 qualifying and willing patients from the rehabilitation units.

Instrumentation

Two bathroom scales, each with a footprint shaped piece of paper pasted on to its surface were used to measure total body weight and the weight transmitted through each limb. A stopwatch was used to measure time periods in the execution of the balance without movement activities. Three chairs were made available for the various tasks involving balance with movement and also as seats to rest patients as and when they felt tired.

The research tool used for this study was the functional standing balance (FSB) scale adapted and modified from Pyoria*et al.,* (2004). Information was recorded on copies of the FSB record sheet.

The first section contained the patients' personal details such as their age, sex, period post-stroke, their affected side, hand dominance and whether or not they had suffered a prior stroke.
The second section was concerned with weight distribution where the total body weight, the masses transmitted through the right and left limbs and the percentage difference in weight bearing were recorded.

The third section was concerned with the balance without movement activities which essentially assessed their ability to maintain balance with a decrease in base of support. Patients were first asked to stand with their feet 20cm apart; the rest of the activities involved decreasing the base of support by means of standing with feet together then single leg standing, first with the non-affected limb and then the affected. Scoring was recorded in terms of the maximum amount of time for which the patient could maintain that position.

The fourth section consisted of the balance with movement activities that involved an assessment of the patients' abilities to maintain balance during the execution of functional activities. These included such activities as bending down to pick an object from the floor; placing objects with both the right and left hands on to a chair; reaching up for objects and turning through 360^0 while standing on the same spot. All the activities for the FSB scale were carefully selected and chosen as being the most common human movements of daily living that posed a constant threat to standing balance.

The maximum total score obtainable from the FSB scale was 47 and a patient with this total had good balance control throughout. The total score for balance without movement was 11 and that for balance with movement was 36.

Pilot study

A pilot study was conducted with four patients at Parirenyatwa hospital using the FSB scale to test the ease and practicality of performing the required tasks. The patients used in the pilot study were not included in the final sample for the research project.

Procedure

Ethical approval was obtained from the Joint research ethics Committee of College of Health Sciences and Parirenyatwa Group of Hospitals (JREC). Permission was then sought from and granted by the relevant administrators to use the departmental facilities of their rehabilitation units. Patients had to give their consent for participating in the study, after the aims and objectives of the study were explained to them.

Data analysis

Due to the small sample size, non-parametric tests were used. Descriptive statistics were reported as median and interquartile range. Correlation coefficients were calculated to determine a relationship between patient performance and the percentage difference in weight bearing through each limb for each patient. Completion of statistical analysis was done using the Statistica Version 13. The level of significance was set at 0.05.

III. RESULTS

Demographic profile and weight distribution

A total of 20 patients participated with 15(75.0%) being females. The median age of the patients was 51.0 (IQR=42-59) years with age ranging from 35 to 74 years. About four patients (20%) were still in the acute stage post-stroke onset while the rest were in the sub-acute to chronic stages ranging from 5 to as much as 158 weeks. Only three patients (15%) had previously suffered strokes prior to the one for which they were attending physiotherapy treatment sessions. An overwhelming majority (70%) of the patients who participated in this study had suffered right sided cerebrovascular accidents with consequent left sided hemiparesis (Table 1).

Table 1. Demographic profile and weight distribution (n=20)

Gender- Female, n (%)	15(75.0)
Age in years, median(IQR)	51.0 (42-59)
Previous stroke, n(%)	
Yes	3(15.0)
No	17(85.0)
Affected side, n(%)	
Left	14(70.0)
Right	6(30.0)
Period Post Stoke in weeks, median (IQR)	11 (5-18)
Total body weight in kgs, median (IQR)	66(57.5-74.5)

Weight distribution in %	
Left	43.0(38.5-48.0)
Right	58.0(49.0-62.5)
Weight distribution in affected limb, %	
Left	39.0
Right	43.0
Weight distribution in non-affected limb, %	
Left	55.0
Right	61.0
Difference in weight in % median(IQR)	19.5(13.0-23.5)

The median total body weight for the study patients was 66(IQR=57.5-74.5) ranging from 45 to 87 kg. An overwhelming majority (95.0%) of the patients carried more weight in the non-affected legs. The average percentage difference between the affected and non-affected sides was 20.0%, the mean mass carried by the non-affected limb regardless of the side being 60% while that of the affected side was 40%. The greatest difference obtained in an individual was 42% in which the non-affected right limb carried 71% of total body weight whereas the left transmitted as little as 29%. A moderate negative correlation (r= -0.573) was found between the percentage difference in weight transmitted through the legs and the score for the balance with movement activities (Figure 1&2). This correlation co-efficient was significant at the 5% level of significance (Table 2).

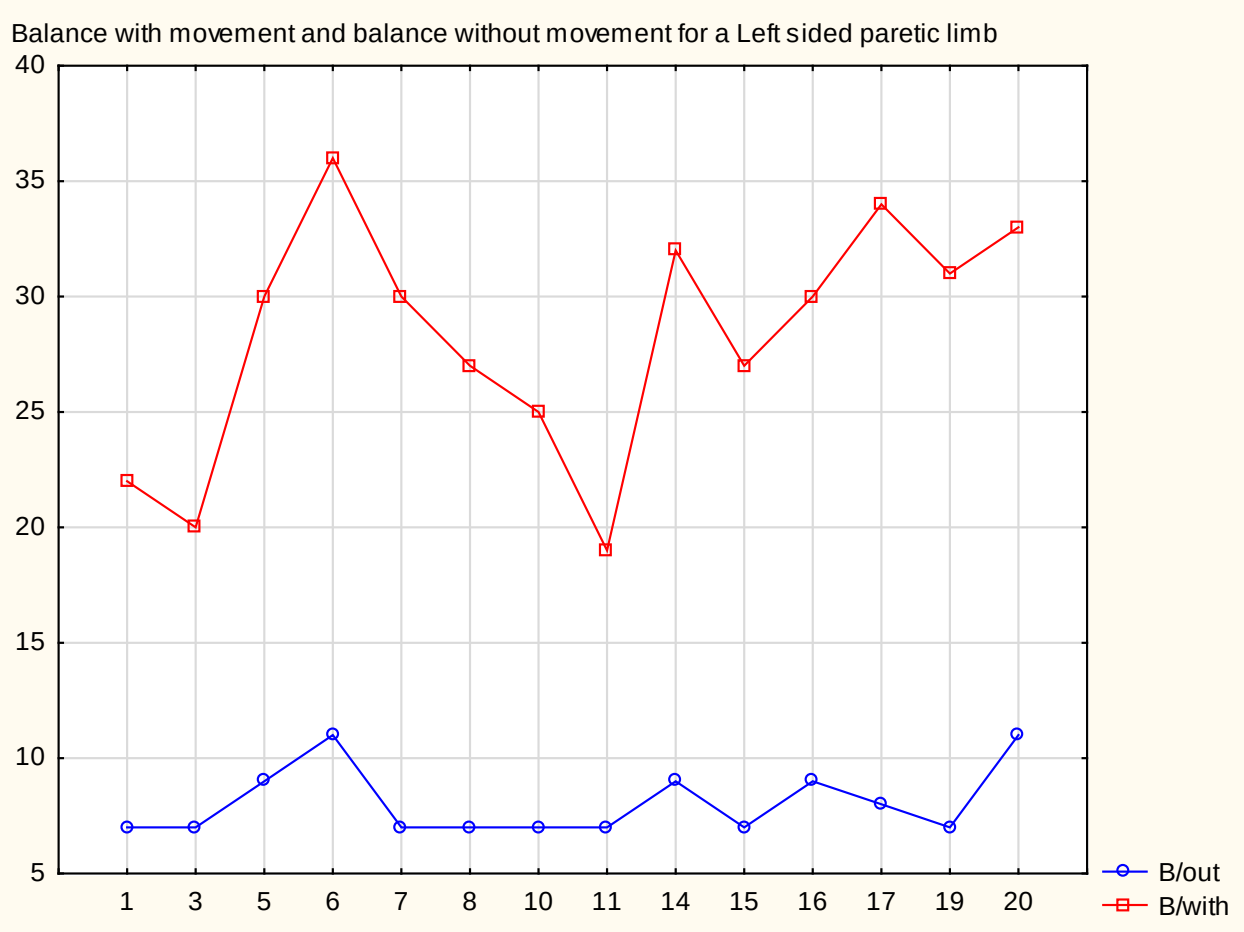

Figure 1. Balance with movement and balance without movement for the left paretic limb

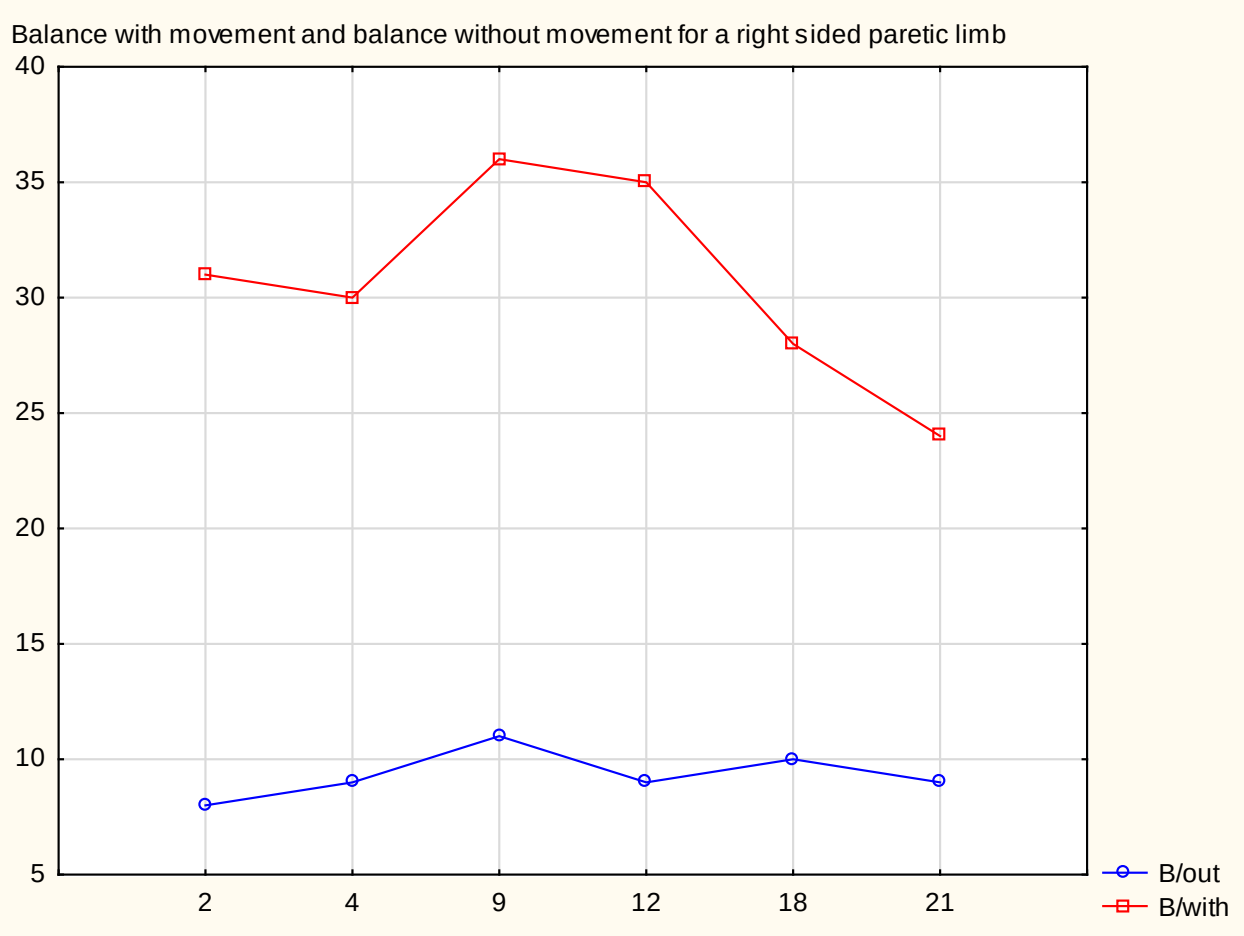

Figure 2. Balance with movement and balance without movement for a right paretic limb

Table 2: Correlations between the various parameters that were studied

	TBW	B/out	B/with	Age	PPS	Rt leg	Lt leg	Diff	Total score
TBW		.2949	.4791	-.0831	-.1585	-.2481	.2655	-.4548	.4674
		p=.207	p=.033	p=.728	p=.505	p=.292	p=.258	p=.044	p=.038
B/out	.2949		.6446	-.3377	.4928	-.3512	.4227	-.2874	.7751
	p=.207		p=.002	p=.145	p=.027	p=.129	p=.063	p=.219	p=.000
B/with	.4791	.6446		-.3293	.3782	-.3150	.2605	-.5698	.9827
	p=.033	p=.002		p=.156	p=.100	p=.176	p=.267	p=.009	p=.000
Age	-.0831	-.3377	-.3293		-.3351	-.1225	-.0513	.0323	-.3540
	p=.728	p=.145	p=.156		p=.149	p=.607	p=.830	p=.892	p=.126
PPS	-.1585	.4928	.3782	-.3351		.0428	.0125	-.1738	.4320
	p=.505	p=.027	p=.100	p=.149		p=.858	p=.958	p=.464	p=.057
Rt leg	-.2481	-.3512	-.3150	-.1225	.0428		-.8861	.4120	-.3454
	p=.292	p=.129	p=.176	p=.607	p=.858		p=.000	p=.071	p=.136
Lt leg	.2655	.4227	.2605	-.0513	.0125	-.8861		-.3902	.3178
	p=.258	p=.063	p=.267	p=.830	p=.958	p=.000		p=.089	p=.172
Difference	-.4548	-.2874	-.5698	.0323	-.1738	.4120	-.3902		-.5406
	p=.044	p=.219	p=.009	p=.892	p=.464	p=.071	p=.089		p=.014
Total score	.4674	.7751	.9827	-.3540	.4320	-.3454	.3178	-.5406	

	p=.038	p=.000	p=.000	p=.126	p=.057	p=.136	p=.172	p=.014	

Tbw= total body weight, b/out=balance without movement, b/with=balance with movement, pps=period post stroke, Rt leg= weight distribution in right leg, Lt leg= weight distribution in left leg, diff= difference in weight distribution between right and left leg, Total Score= the final score of the functional standing balance (FSB) scale.

Balance function with a decrease in base of support

All the patients (100.0%) were able to stand with their feet apart for 30 seconds. When the base of support was reduced to feet together 19 (95.0%) of the patients were able to maintain balance for the maximum amount of time allowed. As the base of support was reduced even further to single leg standing, only 3 (15.0%) managed to stand on the affected limb for the maximum allocated time; 16 (80.0%) were unable to stand on the affected leg for the minimum allocated time of 5 seconds. Of the 14 patients with left hemiparesis, only 7 managed to stand on the non-affected right leg longer than the minimum allocated time whereas all of the individuals with right sided hemiparesis could stand on their non-affected left legs for varying time periods above the minimum allocated.

Balance function in the execution of specified functional tasks

Nine (45.0%) of the patients were unable to control their balance fluently enough to pick an object from the floor with the non-affected hand. One of these (5.0%) completely failed to bend down, experiencing considerable difficulty in maintaining the standing unperturbed position. Most patients (70.0%) experienced some difficulty in maintaining balance when placing objects onto the affected side regardlessof the hand in use. It was more difficult to obtain good balance control while using the affected hand to place objects on the affected side giving them a lower score for the performance than when they used the non-affected hand. In activities that involved reaching with one foot in front 14 (70.0%) patients scored less than the maximum showing that patients demonstrated some compensatory trunk movements. The patients performed with less fluency of balance control when the affected foot was leading than when the non-affected foot was leading. In turning with one foot leading the subjects scored higher when the affected foot was leading than when the non-affected foot was leading.

Total scores for functional standing balance

The median total score for all patients was 38. 5(IQR=33.5-41.5). The percentage difference in weight transmitted by the right and left legs correlated negatively with the total score (r=-.5406 p=.014) (table 2). Correlation coefficients were also calculated between the total score and the total body weight to determine if the patient's body weight had a profound effect on his/her performance (table 2). Statistically insignificant positive correlation was found (r= 4674, p=.038). The total score correlated positively with the period post stroke meaning that as the time period after the stroke attack increased, the patients ability to perform the functional tasks improved (Table 2). The total score correlated negatively with age however, the relationship was statistically insignificant as signified by a p-value greater than 0.05.

Patients that had obtained a low score for balance with a decrease in base of support activities (recorded as balance without movement) went on to obtain low scores in trying to maintain balance in the execution of specified tasks (recorded as balance with movement). The two totals showed a very strong statistically significant positive correlation of 0.6446, p=.002. (Table 2).

IV. DISCUSSION

Weight distribution and asymmetry

The majority of patients (95.0%) carried more weight through the non-paretic limb which value was within the range of values reported in the literature (Sackley*et al.,* 1992; Olaniyi and Akosile., 2012; Chitra and Mishra., 2014). The mean difference of 20% conformed to that reported in the literature by Pyoria*et al.,* (2004) & Mishra and Chitra, (2015). Weight bearing through the non-paretic limb has been reported to range between 61% and 90% (Sackley*et al.,* 1992) the former value of which corresponded well with 60% of total body weight obtained in this study. Aruin*et al.,* (2000) reported a mean of 39% of total body weight transmitted through the paretic limb which value almost coincided with the 40% obtained in this study. Studies that have been carried in the adult population using non-diseased and normal individuals have shown that absolute weight bearing symmetry is not the norm (Sackley*et al.,* 1992). Although some weight bearing asymmetry is known to be present in normal individuals a further decrease in weight bearing through the paretic limb is thought to occur as a result of learned disuse of the affected limb (Lennon and Hastings., 1996; Tyson *et al.,* 2006; Mishra and Chitra., 2015). On average patients carried more weight on the right leg as compared to the left and this was giventhe fact that all the patients who were asked concerning hand dominance were right handed people who preferred to use their right upper and lower limbs.

Balance function with a decrease in base of support

Stroke patients experienced increasing difficulty in maintaining balance as the base of support was gradually decreased. Despite some large weight bearing differences of up to 42%, all the patients were able to maintain the bilateral upright stance for thirty seconds. This indicated that it was only necessary to have both limbs on the ground regardless of the weight they carried. It was stated that contact of any body part with any other surface, even as little as a fingertip contacting the wall, greatly enhanced the patient's balance and affected the reading of the patient's weight bearing measures on the bathroom scales (Carr and Shepherd., 2002). However, as the base of support decreased from feet 20cm apart to feet together, postural sway became more easily detectable and more patients tended to spread their arms to seek more balance or to make it easier to grasp objects if they needed to prevent falling. Quite expectedly, 85.0% of the subjects failed to stand on the affected side for a time period longer than five seconds. Stroke patients tend not to use or to decrease the use of the affected limbs rather favouring

the non-affected one (Lennon and Hastings., 1996; Pereira *et al.*, 2010). This was to a large extent a function of the paretic limb's weakness or flaccidity, but also a psychological problem whereby the patients simply could not consciously rely on a limb which they evidently knew was affected by disuse (Tyson *et al.*, 2006).

Despite the fact that the non-affected leg was expected to be stronger and to carry more weight than the paretic limb, 8 (40%) of the patients in this study were virtually unable to maintain balance in the unilateral upright stance on the non-affected limb. Probably the effect of the stroke on the musculature of the affected side could not be compensated for by muscles on the strong side to bring about sufficient lateral shift of the COM to position it above the BOS in single leg standing. Interestingly, all these patients had right sided stroke all those with left sided CVAs managed to stand on the stronger limbs, albeit for varying periods of time. Laufer*et al.*, 2003 found that patients that had suffered left sided strokes with right side hemiparesis were able to stand independently earlier than those with left sided hemiparesis. However, there did not appear to be any significant differences in reaching other milestones such as function or balance control. It is not clear whether this might be of significance.

Balance function in the execution of various specified tasks

The activities for balance with movement were designed in such a way that they brought about a shift in the COM and the necessity to transfer weight to the weak or strong legs without the patients' awareness. Weight shifting is essential for the efficient execution of functional tasks in activities of daily living (Hwang *et al.*, 2015). Most stroke patients experienced difficulty maintaining balance during the execution of these tasks, especially when the weight had to be transferred to the paretic limb.

Bending to pick an object from the ground

When a patient bent down to pick an object from the ground with the good hand, the muscles on the affected side contracted so that the patient slightly rotated bringing the non-affected side and with it, the non-affected hand forward, using the affected leg as the pivot around which rotation occurred. If this activity was performed while the patient stood on two bathroom scales, it would be noticed that the weight carried by the pivot leg would increase as the patient approached the object (Maki and McIlroy., 1997). Besides this medio-lateral weight shift, bending down also had the tendency to bring about an anterior sway of the COM. In carrying out this activity the patient had the additional task of preventing the anteroposterior sway without change-in-support strategy for balance maintenance (Maki and McIlroy., 1997). The one patient that failed to bend down had poor knee control and could only maintain the leg in extension by locking the knee, ensuring that the joint was always posterior to the line of action of gravity. Three people (15%) failed to reach the ground without sidestepping and changing the base of support. This was attributed to lack of practice in executing such movements (Mclellan and Ada., 2004) as it was something that none of the therapists had taught their patients.

Placing an object towards the affected and non-affected sides

The activities that required the patient to place an object on a chair placed towards his affected and non-affected sides led to a greater shift of the weight towards the side opposite to the hand in use. In themselves, these activities had the added effect of requiring the patient to protract the affected upper limb when using it to place an object on a chair on the affected side, while maintaining balance with the affected lower limb bearing the greater weight (Pyoria*et al.*, 2004). In this case the affected leg was forced to carry more weight than the non-paretic limb which if weak, led to a disturbance of balance control, especially in a patient that was not used to it. In 40% where there was presumably more involvement of the abdominal and trunk musculature by the stroke, patients experienced more difficulty placing objects on the affected side using the affected limb. There probably was a lack of balance in the lateral rotators of the trunk leading to an absence of proximal stability thus poor balance (Nichols, 1997). As might have been expected, higher scores were recorded when patients had to rely on the non-paretic limb in placing objects on the non-paretic side owing to its strength and stability.

Reaching with one foot in front

The activities that involved reaching required the patient to shift their weight on to the foot in front while trying to reach with the non-affected hand. Use of the non-affected limb was because most patients could hardly lift the stroke affected hand above the shoulder due to paralysis or muscle weakness (Pyoria*et al.*, 2004). Most patients found this activity difficult to perform since it required the transfer of almost the whole weight to the foot in front; however it differed from single leg standing in that the other limb maintained contact with the ground. As the patient reached, there was an anterior shift of the COM on to the foot in front. The patient's task was to prevent the extreme anterior sway beyond the leading foot while at the same time concentrating in reaching for the top of a shelf. In any case, the patientscored higher when the weight had to be transferred onto the non-paretic limb. The patients did score well however even with the affected foot leading as they had the ability to compensate for balance by maintaining floor contact with the other limb. It seemed that most patients tended to keep their COM somewhere between the two limbs.

Turning with one foot leading

In turning with one foot leading, most of the weight was carried by the non leading foot which was the pivot foot. When the affected foot was leading, the patients scored higher since the non-paretic stronger limb was the weight bearing and pivot limb. The major advantage with these activities was that besides being activities that could be used to educate a patient to transfer weight on to the paretic limb, they could also be used to test the patient's ability to maintain balance. The activities were specially selected after having considered the most basic of human movements of daily living that required constant weight shifting and balance control.

Overall score

There was moderate negative correlation between the weight difference and the score for balance with movement activities. This meant that an increase in the asymmetry of

weight distribution between the right and left legs led to a decrease in the score for balance with movement activities. The execution of these functional activities in standing required that a patient be stable on his/her feet and be able to shift significant weight to either limb (Gunes*et al.*, 2001). Therapists are encouraged to train weight shifting and transference to the paretic limb as there is reported significant potential for the central nervous system to reorganize itself after a stroke and take up some lost function (Lennon and Hastings, 1996).Studies on patients that have received treatments aimed at addressing large weight discrepancies have shown significant improvements after as little as 2 weeks of treatment (Mishra and Chitra., 2015). The insertion of a 10mm insole along with conventional therapy led to improvements in the symmetry of balance post stroke (Chitra and Mishra, 2014). Patients that had left sided hemiparesis performed better than their counterparts with right sided hemiparesis. This result suggested the likelihood that right-sided CVAs probably had a better prognosis than the left sided ones. However, according to Wade *et al.*, (1985) it seemed highly unlikely that the side of the stroke itself was of prognostic value for the patient but that particular deficits are more important. This was insofar as the side of weakness was associated with loss of other specific functions which needed particular rehabilitative attention for recovery for example, in this study only one person had a speech problem of note. Laufer*et al.*, 2003 found that patients with left sided strokes with right side hemiparesis were able to stand independently earlier than those with left sided hemiparesis. However, there did not appear to be any significant differences in reaching other milestones such as function or balance control. The numbers of patients studied here were insufficient for any large scale generalisations to be made and the inclusion criteria meant it was not possible to determine the side of lesion for those patients that were excluded. A moderate positive correlation between the period post-stroke and the total scorewas observed. This meant that performance improved with an increase in time post stroke as expected. This occurred because the patient gained more confidence in using the paretic limb as a result of an increase in strength and coordination from rehabilitation and also development of methods to compensate where there was weakness. Physiotherapy was key to improvement, an example may be given of a patient that had suffered a stroke twelve weeks previously but was attending rehabilitation for the first time and experienced difficulty in getting up. This concurred to what is reported in the literature whereby it is said that prior stroke was a consistent predictor for poor prognosis post stroke (Gunes*et al.*, 2001).

V. CONCLUSIONS

From the results of this study it was concluded that the standing balance of stroke patients were linked to uneven weight distribution. There was a relatively large difference in the mean percentages of total body weight carried by the affected and the non-affected limbs. An increase in weight bearing asymmetry correlated with a decrease in the ability to perform functional activities in standing. Therapists should therefore be encouraged to address this asymmetry in managing stroke patients.

COMPETING INTERESTS

The authors declare no conflict of interest.

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AUTHORS

First and corresponding Author -Samson Chengetanai.-MSc Medicine (Anatomical Sciences), BSc (Hons) Physiotherapy, BSc (Hons) Anatomy. Lecturer. Department of Anatomy and Physiology, Faculty of Medicine, National University of Science and Technology, PO Box AC 939, Ascot, Bulawayo, Zimbabwe. Cellphone number:+263 783209804. Email add: schengetanai@gmail.com

Second author-CathrineTadyanemhandu-MSc Physiotherapy, BSc (Hons) Physiotherapy, Lecturer. Department of Rehabilitation, College of Health Sciences, University Of Zimbabwe, PO Box AV 178. Avondale, Harare, Zimbabwe. Cellphone number: +263 773 430 792. Email add: cathytadya@gmail.com

Third author-Fidelis Chibhabha.-MSc Med Human Anatomy, BSc (Hons) Physiotherapy, BSc (Hons) Human Anatomy. Lecturer.Department of Anatomy, Faculty of Medicine, Midlands State University, PO Box Gweru, Zimbabwe. Cellphone number:+263 773 257 490.Email add: fchibhabha@gmail.com

Fourth author-FarayiKaseke.-MSc Physiotherapy, MSc Strategic Management, BSc Physiotherapy. Lecturer. Department of Rehabilitation, College of Health Sciences, University Of Zimbabwe, PO Box AV 178. Avondale, Harare, Zimbabwe. Cellphone number: +263 772 890865. Email add:farayi.kaseke@gmail.com