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Can Quantitative Balance Measures Discriminate between Functional Ambulation Categories in Chronic Stroke Survivors?

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Abstract

Background: The limited walking ability that follows a stroke restricts a patient's independent mobility about the home and community, a significant social handicap. This study investigated the relationship between quantitative balance indices and functional ambulation level in stroke patients. The purpose was to explore whether we could provide supportive laboratory evidence for the association between balance and ambulatory level in stroke patients based on computerized dynamic post urography.

Study design: Cross-sectional, observational, descriptive study

Setting: Physiotherapy department in a tertiary care center in Mumbai

Participants: 40 ambulatory stroke patients (mean age=54.07 ± 11.9 years)

Main outcome measures: (1) Static and dynamic balance was assessed using computerized force plate system

(2) Functional ambulation level was determined using Modified Hoffer functional ambulation classification (FAC).

Results: According to FAC, 29.26% of the patients were community walkers. One way ANNOVA showed that static and dynamic balance indices were significantly different with functional ambulation categories. Weight bearing asymmetry during quiet stance ($p<0.04$); COG sway velocity ($p<0.04$), weight transfer time ($p<0.04$) and rising index ($p<0.02$) during sit to stand can discriminate between household and community ambulators.

Conclusion: Balance is a significant factor in the attainment of independent functional ambulation in chronic stroke patients. The functional mobility capability of stroke patients may be quantified analytically using static and dynamic balance indices. The key balance factors identified through this study need to be specifically targeted for training and as outcome measures while monitoring the progress of patients through different functional ambulation categories. Results of this study offer a quantitative method of relating the social disadvantage of stroke patients to the impairments.

Keywords: Stroke; Balance; Gait speed; Functional ambulation

Introduction

Stroke is the third leading cause of adult disability [1]. The limited walking ability that follows the stroke restricts a patient's independent mobility about the home and community resulting into a significant social handicap. Regaining the ability to walk independently is the most important functional goal in rehabilitation of stroke patients. Functional ambulation is the ability of a person to walk with maximal independence while spending the shortest time under various environmental circumstances [2]. Functional ambulation is context-specific. Environmental factors in Indian context could be different and there is lack of published data in Indian population. Despite the efforts taken to achieve good mobility outcomes, most of the stroke survivors do not get out in the community [3-6]. There is no consensus to date on what factors are most important in predicting those who will return to independent community ambulation.

Although there is no established or gold criterion specifically for the assessment of functional ambulation, the most widely used quantitative method to measure walking ability after stroke is walking velocity [7,8] It has been suggested by many authors as a measure that determines and discriminates between different categories of functional ambulation. Gait speed is an important factor related to community walking; however, ability to walk in the community is determined by several underlying factors, e.g. balance, motor function, endurance and assistive walking device, etc. [9,10].

Of all possible sensorimotor consequences of stroke, impaired postural control probably has the greatest impact on ADL independence and gait [11-14]. Following stroke, patients often have disturbed balance and postural control leading to impairments in steadiness, symmetry, and dynamic stability [15]. This can cause problems in reactive postural control and anticipatory postural control alike. The disruption of central sensorimotor processing makes it difficult to adapt postural movements to the changing demands of a task or environment. Patients' responses to destabilizing forces are frequently insufficient and result in loss of balance and falls. Previous studies have highlighted that balance contributes to ambulatory function in stroke survivors and balance deficit has been associated with low level of ambulatory function [16]. Majority of these studies have focused on gait velocity and gait pattern using either clinical and laboratory gait assessment tools. However, limited evidence exists as to how balance impairments relate to functional ambulation in stroke

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patients. The Berg Balance Scale is psychometrically sound measure of balance impairment and is identified as the most commonly used assessment tool across the continuum of stroke rehabilitation [17]. However, given the floor and ceiling effects and other limitations, clinicians may want to use the BBS in conjunction with other balance measures. Instrumented tools such as force platform assessment may augment clinical balance tests by providing quantitative information on postural sway, weight-bearing asymmetry and weight- shift control during balance activities [18,19]. These technologies have been found to possess good to excellent reliability for static and dynamic balance assessment in stroke. Concurrent validity is established with berg balance scale and gait speed.

The purpose of this study was to explore whether we could provide supportive laboratory evidence for the association between balance and ambulatory level in stroke patients based on static and dynamic balance indices. We hypothesized that instrumented balance assessment would be a useful tool to identify specific balance impairments and distinguish across various functional ambulation categories in stroke patients. Investigation of balance factors specific to functional ambulation may be helpful in determining and targeting appropriate treatment for gait rehabilitation in stroke.

Methodology

It was a cross-sectional analytical study conducted in a tertiary care centre. A convenient sample of 40 hemiplegic stroke individuals was recruited from an outpatient rehabilitation unit in Mumbai, India. Institutional review board approved design and conduct of the study. The procedures followed protocol and accord with the ethical standards of the institutional review board. Informed written consent was obtained from all the participants before participation in the study.

Baseline evaluation for eligibility entailed a comprehensive history, physical, and neurologic examination. Demographic characteristics, history of fall/s after the onset of stroke, use of ambulatory aid/s was obtained. Because patients with either right or left hemiplegia were included in the study and cognitive or visual-perceptual issues might affect the patients' ability to perform on the balance master, a detailed assessment of these skills was done before their enrolment in the study. 40 stroke patients who met the inclusion criteria participated in the study. Inclusion criteria: 1) unilateral, hemiplegic involvement, 2) Able to follow three-step commands, MMSE score>24, 3) Ability to get up from a chair without assistance, 4) Able to maintain stationary standing position with or without an assistive device for a minimum of 2 consecutive minutes without manual assistance, 5) Ambulatory with or without assistance, 6) Living in the community. Patients were excluded from participation if they had 1) a history of previous stroke or other neurologic diseases or disorders, 2) musculoskeletal problems that can affect balance or mobility, 4) uncorrected visual impairments, 5) vestibular impairments, 6) perceptual deficits, 5) previously trained using balance master, 7) medically unstable.

All the assessment was carried out by the same investigator. To avoid the effect of fatigue on balance and gait parameters sufficient rest periods were given during testing in between assessments.

Outcome measures

Static and dynamic postural control was assessed using computerized force plate system- balance manager (Neurocom International version 8.6.0) (Figure 1). All the tests were performed in a standardized manner.18 Use of assistive devices was prohibited during the test.

Static balance: Patient was made to stand on the force plate (firm surface) under eyes open condition (only first part of mCTSIB test). For this test, COG sway velocity (degrees/second) was measured. 3 readings were recorded and average value was noted for each condition. Under similar test condition (only 1st part of weight bearing squat test in which patient stands erect with 00 of knee extension), Weight Bearing Asymmetry (WBA) was recorded as difference in the percentage of body weight borne by each leg (Figure 2).

Dynamic balance: Dynamic balance was evaluated using Sit to stand test (STS) protocol. The STS quantifies the patient's ability to rise from a seated to a standing position. Key components of this task include shifting the body COG forward from an initial position over the seat to a location centered over the base of support, followed by extension of the body to an erect stand while maintaining the centered COG position. The measured parameters were weight transfer time, rising index, sway velocity after rising phase, and left/right symmetry of the rising force.

- Weight Transfer is the time in seconds required to voluntarily shift COG forward beginning in the seated position and ending with full weight bearing on the feet.
- Rising Index is the amount of force exerted by the legs during the rising phase. The force is expressed as a percentage of the patient's body weight.

Figure 1: Balance Manager System.

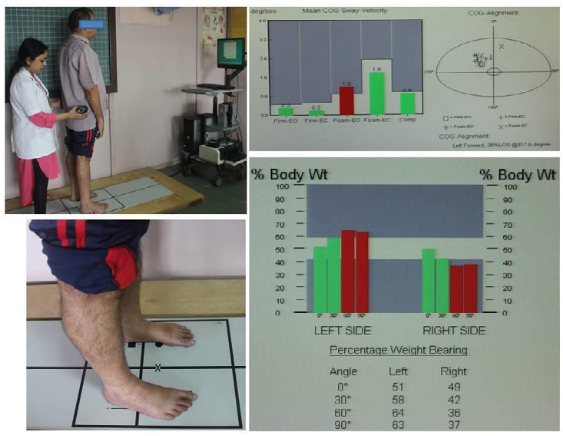

Figure 2: Quiet Stance on Balance Manager System.

- COG Sway Velocity documents control of the COG over the base of support during the rising phase and for 5 seconds thereafter. Sway is expressed in degrees per second.
- Left/Right Weight Symmetry (WBA) documents differences in the percentage of body weight borne by each leg during the active rising phase (Figure 3).

Functional ambulation level: Functional ambulation level (Figure 4) was determined using Modified Hoffer functional ambulation classification [3]. The patient's level of functional walking ability at home and in the community was assigned by the investigator to one of the six categories as per the criteria after his/her gait was examined and certain data were obtained by questioning the subject. The degree of walking independence, agility, and safety was assessed, as was information obtained directly from both patients and their relatives. Attention was given especially to the patient's ability to deal with different surroundings. Only the patient's usual walking level was considered, not the level he/she could potentially achieve.

Data thus collected was subjected to statistical analysis.

Results and Discussion

Demographic characteristics of the participants are given in Table 1.

All the participants were at least 6 months post stroke and were receiving rehabilitation therapies. The mean (± SD) duration since stroke was 15.18 (± 19.33) months, however, only 40% of the participants had achieved community ambulation according to FAC. Similar figures on community mobility have been reported in previous studies on post-acute stroke survivors using performance-based and/or self- reported outcome measures [5,6,20] (Table 1).

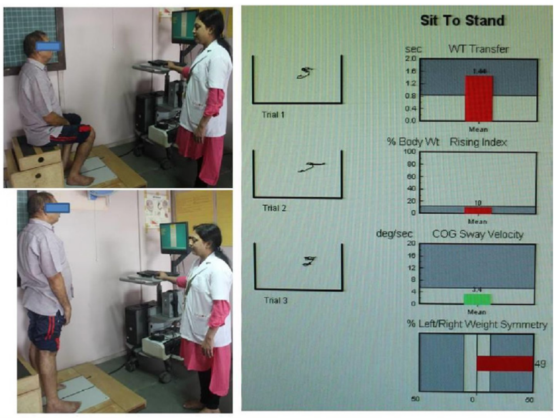

Figure 3: Sit to stand on Balance Manager System.

Characteristic		Value
Age (in years) mean ± SD		58.4 ± 8.12
Gender: M/F		2:03
Time post stroke (in months) mean ± SD		15.18 ± 19.33
Side of hemiplegic involvement: Right/Left		2:03
Walking aid (% of patients)	None	27
	Single-pointed cane	28
	Quad cane	42
	Walker	3
History of fall (after stroke)		None

Table 1: Participants' characteristics.

Participants of the study were stratified according to the level of functional ambulation into six different categories as determined by the FAC. Statistical analysis was done using a computerized software.

All the variables were examined by descriptive statistics. The balance indices served as the independent variables whereas the functional ambulation level served as the dependent variable in the association model. Variables distribution was tested using Kolmogorov-Smirnov test which exhibited normality, and therefore parametric test was used for all the analyses. The test applied was one way ANNOVA with post-hoc analysis. 2-tailed significance level of p value was set at 0.05.

Table 2 and Graphs 1 to 6 show the comparison of variables measured using balance master among the different groups stratified by functional ambulation classification (Table 2) (Figures 5-10).

It was observed that static and dynamic balance indices were significantly different with functional ambulation categories. Except the difference in COG sway velocity during quiet stance was not significant between any of the categories.

Among all the balance parameters, WBA during quiet stance ($p<0.04$); and COG sway velocity ($p<0.04$), Weight transfer time ($p<0.04$) and Rising index ($p<0.02$) during Sit to Stand were significantly different between the broad categories of Household ambulators (n=24) and Community ambulators (n=16).

Analysis between sub-categories identified differences in following parameters:

- Between Physiological walker and Limited household walker significant difference was observed for WBA during quiet stance ($p<0.02$), COG sway velocity ($p<0.03$) and Weight transfer time during sit to stand ($p<0.02$).
- WBA during Quiet stance ($p<0.02$) and Sit to Stand ($p<0.04$)

Figure 4: Functional Ambulation Categories (adapted from Perry J, et al. 1995).

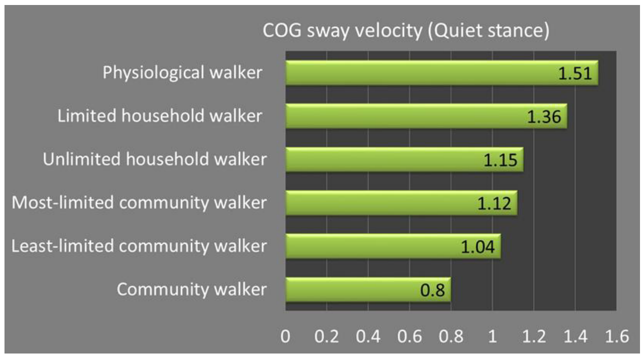

Figure 5: COG sway velocity during quiet stance.

		Functional Ambulation Categories					
Test	Variable	PW	LHW	UHW	MLCW	LLCW	UCW
		n=7	n=15	n=7	n=5	n=4	n=3
Quiet stance	COG sway velocity (deg/sec)	1.51 ± 0.31	1.36 ± 0.42	1.15 ± 0.26	1.12 ± 0.13	1.04 ± 0.28	0.8 ± 0.01
	WBA (%)	25.06 ± 0.11	17.14 ± 0.14	11.75 ± 0.91	11.14 ± 1.12	10.4 ± 1.23	8.66 ± 2.3
	COG sway velocity (deg/sec)	4.5 ± 0.23	3.56 ± 0.13	3.51 ± 0.22	3.4 ± 0.51	3.2 ± 0.9	2.9 ± 0.44
Sit to Stand	WBA (%)	31.46 ± 5.65	29.28 ± 2.34	21.25 ± 1.29	18.71 ± 2.89	16 ± 1.56	8.8 ± 0.98
	WTT (sec)	1.96 ± 0.2	1.03 ± 0.71	0.85 ± 1.1	0.58 ± 0.12	0.59 ± 0.22	0.46 ± 0.18
	RI	11 ± 0.4	11.14 ± 1.23	11.42 ± 1.52	13.48 ± 5.1	13.65 ± 3.82	16 ± 2.1

Table 2: Comparison of balance indices among the different groups stratified by functional ambulation classification; Values are expressed as mean ± SD; PW=Physiological walker; LHW=Limited household walker; UHW=Unlimited household walker; MLCW=Most limited community walker; LLCW=Least limited community walker; UCW=Unlimited community walker; COG=Center of Gravity; WBA=Weight Bearing Asymmetry; WTT=Weight Transfer Time; RI=Rising Index.

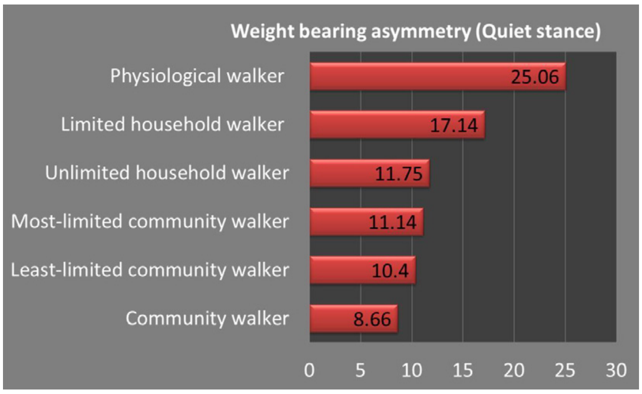

Figure 6: Weight bearing Asymmetry during quiet stance.

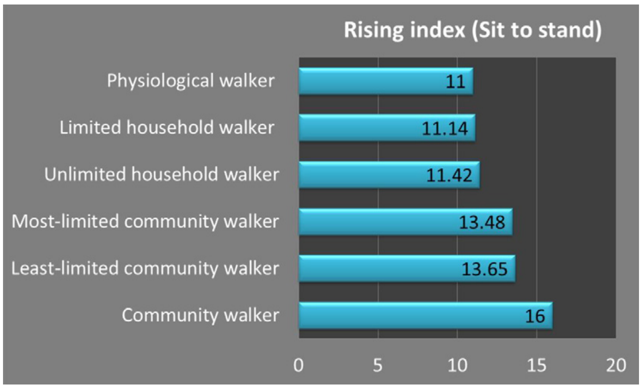

Figure 8: Rising Index during Sit-to Stand.

Figure 7: Weight Transfer time during Sit-to Stand.

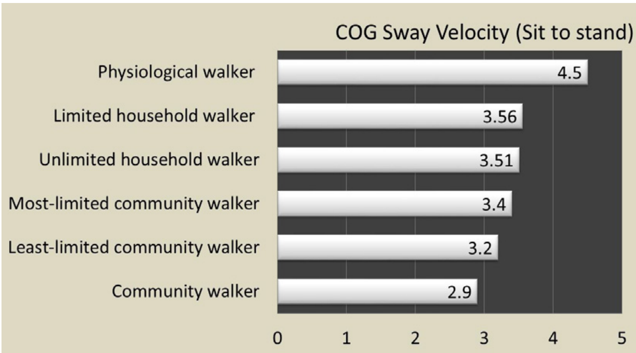

Figure 9: COG Sway Velocity during Sit-to Stand.

differentiated between Limited household walker and Unlimited household walker.

- Significant difference was observed in the category of least limited community walker as compared to Community walker during Sit to Stand for WBA ($p<0.02$) and Rising Index ($p<0.03$).
- Weight transfer time during Sit to Stand was statistically different for unlimited household walker versus Most-limited community walker ($p<0.02$).

Balance manager system is considered as the gold standard of Computerized Dynamic Post urography. The impairment assessments and functional limitation assessment protocol used in

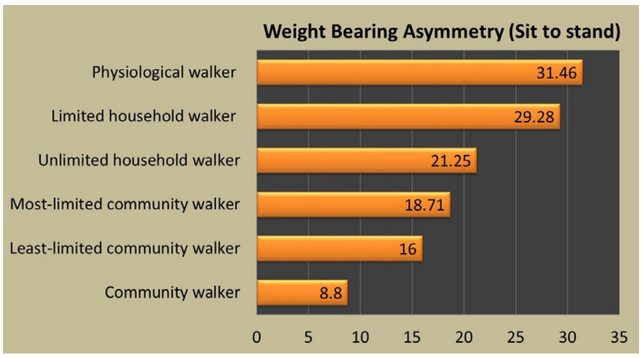

Figure 10: Weight Bearing Asymmetry during Sit-to Stand.

this study complement clinical information and accurately isolate and differentiate sensory and motor system impairments underlying a patient's functional limitations and disabilities [18]. Assessments of motor impairments evaluate the effectiveness of automatic and voluntary motor systems in controlling balance and mobility and are particularly sensitive to limitations in performance resulting from deficits in lower extremity weight distribution, range of motion, and motor control.

Previous studies using force plate analysis have shown that postural sway can be twice that of their age-matched peers [21]. Symmetry of weight bearing is also impaired following stroke, with patients bearing as much as 61% to 80% of their body weight through their non-paretic lower extremity [22]. All these findings imply impairments in steadiness, symmetry; and dynamic stability especially impaired planning and coordination of weight transfers; problems in reactive as well as anticipatory postural control. Each hemi paretic patient with stroke can have unique combinations of postural abnormalities. Owing to the diverse mechanisms involved in postural control, decreased muscle strength, range of movement, abnormal muscle tone, motor coordination, sensory organization, multisensory integration, [23] cognition [24] and can contribute to balance disturbances at different levels.

The results of this study demonstrated that chronic hemi paretic subjects with different levels of functional performance showed differences in parameters related to the balance during quiet stance and sit-to-stand movement assessed by the balance manager system. Individuals who had lower functional performance levels (household ambulation) spent more time to perform sit-to-stand movement with less weight transfer to the lower limbs. Findings of this study suggest that within clinical contexts when balance training is carried out to improve mobility and gait performance in individuals with household ambulation, parameters related to the transfer time and rising index during sit to stand should be emphasized. Thus, overall the specific balance parameters implicated for a difference in ambulation category should be targeted for training for taking the patient from lower to the next higher level of functional ambulation.

Consistent with the finding of the present study, previous studies have also indicated that balance control is related to ambulatory function and has the ability to predict walking performance [9,12,14,25] These studies have found that the motor control patterns and dynamic balance correlated well to the extent of mobility impairment evaluated using different measuring tools viz. Berg Balance Scale, Sit-to-Stand, Timed Up and Go test, FIM etc. in stroke patients. It is important to mention that majority of these studies have used clinical measures and have tested walking performance in a structured environment. Literature search conducted for the present study identified only one study which assessed the influence of weight bearing asymmetry on functional ambulation performance assessed using the Emory Functional Ambulation Profile and found a significant correlation [2]. Thus, an important highlight of the present study is that we analysed this relationship more objectively and in the context of functional ambulation which can be considered as a more clinically meaningful outcome for stroke rehabilitation. Another important conclusion for rehabilitation medicine is that the functional mobility capability of stroke patients may be quantified analytically using static and dynamic balance indices.

Although laboratory measurements are not widely available, they can provide precise information and should be combined with clinical evaluation whenever possible to enhance comprehension of postural impairments and disabilities in hemi paretic stroke patients. These data can be used to better define the goals of a therapy program, monitor progress, and document the outcome of therapy more specifically across the continuum of stroke rehabilitation. All the assessment protocols of Computerized Dynamic Post urography are consistent with the World Health Organization International Classification of Function (WHO-ICF) and have been validated by extensive scientific and clinical research [18]. The WHO-ICF (2001) is an amalgam of the medical and social models and brings into focus the interaction of the body's structure and function, activities, and participation in life situations (Figure 11) [26]. The diagram identifies three levels of human functioning classified by ICF: functioning at the level of body or body part, the whole person, and the whole person in a social context. Disability therefore involves dysfunctioning at one or more of these same levels: impairments, activity limitations and participation restrictions. With the advent of WHO-ICF model, health professionals are encouraged to evaluate and consider the impact of stroke more comprehensively. In order to adequately address decreased post-stroke activity and participation, it is important to understand the factors that contribute to this reduction. Current clinical tests evaluate walking balance on an activity level by describing the ability to complete a task and/or the time needed to complete a task. These tests do not specifically evaluate balance on the level of body function, as these levels are described in the ICF. By evaluating walking balance on an activity level only, it remains unclear if an individual stroke survivor functionally recovers by restitution or by learning to compensate for the lack of restoration of body function. To get these insights in walking balance and body function, an objective assessment of body function during walking is required. Also, the influence of balance impairments on stroke survivors' ability to negotiate obstacles and move over different terrains (functional ambulation performance) has not received much attention in literature. To the best of our knowledge, this is the only study which attempted to associate impairments (balance indices) with the activity limitation (walking) and participation restriction (functional ambulation) in stroke patients.

However, we acknowledge several limitations in the present study. The use of one outcome measure does not fully explain a person's activity or participation capacity after stroke [27]. Possible confounding factors which may affect functional ambulation viz. spasticity, weakness, executive function, depression, fatigue, walking endurance, and self-efficacy etc. were not considered in the study. Inter hemispheric differences were not considered in the analysis. The number of patients was not equally distributed among the functional

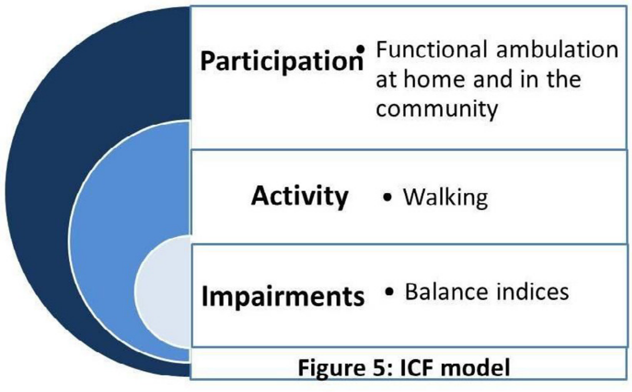

Figure 11: ICF Model.

classification categories. The present study is cross- sectional, whereas a previous longitudinal study has shown that mobility outcome is not stable but time-dependent. For example, it was found that approximately 20% of 205 relatively young chronic stroke victims significantly deteriorated from 1 to 3 years post-stroke [28]. Therefore, we also expect that community ambulation will gradually change as a function of time after stroke and recommend future studies to have a longitudinal design to determine the dynamic relationship of variables with community ambulation by conducting longitudinal studies.

Conclusion

Balance is a significant factor in the attainment of independent functional ambulation in chronic stroke patients. Static and dynamic balance indices are significantly different with functional ambulation categories in ambulatory stroke patients. An important conclusion for rehabilitation medicine is that the functional mobility capability of stroke patients may be quantified analytically using static and dynamic balance indices.

Implications for Rehabilitation

Considering the important relationship of balance and functional ambulation in chronic stroke patients, Physiotherapy interventions addressing community ambulation post-stroke should consider methods for improving balance and mobility in chronic stroke. Results of this study offer a qualitative method of relating the social disadvantage of stroke patients to the impairments as per the ICF model.

The key balance factors identified through this study need to be specifically targeted as outcome measures while monitoring the progress of patients through different functional ambulation categories. The clinicians should focus on remediating more specific impairments pertaining to different functional ambulation categories. Due to specific, more objective and quantitative nature of the data obtained using computerized system; results of this study are useful for evidence based treatment planning.

Implications for Future Research

We suggest studies on larger sample of stroke survivors to establish discriminative validity of balance indices for functional ambulation. Balance training should consider community ambulation as one of the outcome measures in stroke rehabilitation. Considering the dynamic interactions of multiple impairments following a stroke and multifactorial nature of functional ambulation, it is reasonable to expect that different outcome measures would relate differently to the activity and participation domains of the WHO-ICF model. More studies using different outcome measures will assist therapists in designing optimal rehabilitation interventions to target recovery and to track a patient's progress during therapy in each of these domains from various perspectives. There is currently insufficient evidence to establish the effect of community ambulation interventions or to support a change in practice. More research is needed to determine if practicing outdoor or community walking will improve participation and community ambulation skills for stroke survivors living in the community.

Conflict of Interest

The authors hereby declare that there was no Conflict of Interest.

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