Research Article

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Journal of Physiotherapy Research

2018
Vol.2 No.5:13

The Percentage of Occurrence of Turning Difficulty in Hemiplegic Stroke Survivors

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Received date: November 20, 2018; **Accepted date:** November 26, 2018; **Published date:** December 03, 2018

Citation: Liang PJ, Chen JY, Lee SC (2018) The Percentage of Occurrence of Turning Difficulty in Hemiplegic Stroke Survivors. J Physiother Res. Vol.2 No.5:13.

Abstract

Background: Turning difficulty has been reported after stroke. However, the percentage of occurrence has not been determined. Exploration into the association between turning and trunk function and activities of daily living (ADL) has been limited. This study aims to calculate the percentage of occurrence of turning difficulty after stroke, and investigate the relationship between turning and measures of physical impairments, balance, walking ability, and ADL in stroke survivors.

Methods and findings: All participants were evaluated on their turning performance. SPs received an additional assessment of the Chedoke-McMaster Stroke Assessment Inventory (CMSA), Trunk Impairment Scale (TIS), Berg Balance Scale (BBS), Falls Efficacy Scale International (FES-I), 10-meter walk test (10MWT), and Frenchay Activity Index (FAI). The results showed that more than half of participating SPs were determined to experience turning difficulty in terms of turn time (53%), number of steps taken (57%), strategy (100%), and balance (70%). A moderate correlation was found between turn time and balance and all of the remaining measurements, with the exception of the FES-I and FAI. The number of turn steps and strategy were not correlated with any other measurements.

Conclusions: The majority of SPs suffered from turning difficulty identifying by over 3 seconds of turn time, at least five turn steps, an ineffective step strategy with instability during turning. Their turning performance was moderately associated with motor recovery of the paretic lower limbs, trunk control, balance, and walking ability but not correlated to concerns about falling and ADL.

Keywords: Activities of daily living; Occurrence; Stroke; Trunk control; Turning difficulty

Introduction

Up to 40% of steps taken in everyday walking are turns [1], which speaks to the importance of the movement in daily living. However, turning has been reported as one of the activities that most frequently lead to falling for stroke patients (SPs) [2]. Previous studies reported that stroke survivors required more time and a greater number of steps to complete turns than age-matched healthy controls (HCs) indicating the presence of turning difficulty after stroke [3-6]. It is not surprising that stroke survivors performed worse during the turn because of the impaired posture and movements caused by hemiparesis, however, turning difficulty should be identified by assessing not only the turn time and the number of steps taken but also the strategy and balance according to Thigpen et al. [7].

Muscle weakness of the lower limbs, motor impairments, and abnormal walking capacity are evident after a stroke and are associated with turning difficulty [5,8,9]. Trunk control is crucial for maintaining stability and an upright position during sitting, standing, walking, and possibly turning [10,11]. Decreased or delayed muscle contraction in trunk rotators after a stroke may lead to turning dysfunction [12]. The concerns about falling during the performance of daily tasks and the level of dependence experienced by SPs during activities of daily living (ADL) could be exacerbated due to the frequency of turning in everyday life. However, research in this area is limited.

Therefore, the purposes of this study were to examine the differences in turning performance between SPs and HCs with regard to turn time, number of steps, strategy, and balance, and also calculate the percentage of occurrence of turning difficulty after stroke. The secondary objective was to investigate the relationship between turning performance and measures of physical impairments, balance, walking ability, and ADL in hemiplegic stroke survivors.

Methods

Subjects

SPs were recruited from a regional hospital in New Taipei City, Taiwan. The inclusion criteria were (1) survivors of a single stroke with hemiparesis experienced at least three months prior to their participation in the study, (2) able to walk independently over a distance of 10 meters without walking aids or orthoses, and (3) able to give informed consent and follow instructions. The exclusion criteria were (1) having additional musculoskeletal conditions or comorbid disabilities that could affect the assessment, and (2) having cognitive problems or aphasia that could prevent subjects from following instructions. Healthy adults were recruited from the local community and were also excluded if they had any neurological or musculoskeletal conditions that could influence normal balance or affect the assessment procedure. All participants gave written informed consent prior to taking part in the study, which was approved by the Taipei Tzu Chi Hospital, Buddhist Tzu Chi Medical Foundation Institutional Review Board.

Protocols

All participants were evaluated on their turning performance. SPs underwent additional assessments for physical impairments, balance, walking ability, and performance of ADL. The patients were prohibited from using orthoses or walking aids during the assessment.

Turning performance

Turning performance was assessed throughout a 180° on-the-spot turn at a comfortable pace and recorded using a video camera (FUJIFILM F200EXR, Japan). Participants stood facing away from the camera at distance of 3 meters and performed one practice test and one actual test in each direction. Participants chose the direction in which they preferred to turn first. All of the footage was observed and analyzed by two researchers (Chen and Lee). The initiation and termination of foot movements were determined as the beginning and the end of the 180° turning. The numbers of steps taken to complete the turn were counted and the turn time was recorded using a stopwatch. The turn strategy and turn balance were analyzed and categorized according to the methodology described by Thigpen et al. [7].

Physical impairments

Physical impairments were assessed using the Chedoke-McMaster Stroke Assessment Inventory (CMSA) [13] and Trunk Impairment Scale (TIS) [14]. The CMSA assesses the stage of motor recovery in the paretic leg and foot based on the Brunnstrom stage theory. The assessment is scored along a 7-point scale. The TIS evaluates the SP's trunk control ability after stroke. It consists of static and dynamic sitting balance tests and evaluation of trunk movement coordination. The scoring range for the TIS is '0' for the poorest performance to '23' for a perfect performance.

Balance

Balance ability was objectively assessed using the Berg Balance Scale (BBS) [15] and subjectively by the Falls Efficacy Scale International (FES-I) [16]. The BBS is a widely used clinical test of a person's static and dynamic balancing abilities. It is composed of 14 balance related tasks including rising from a sitting position to a standing position, transferring weight, and standing on one foot. Each item consists of a 5-point ordinal scale ranging from '0' to '4.' The lowest level of function is indicated by a '0,' and '4' indicates the highest level of function. The total score is 56, with the highest total score indicating the lowest risk of falling. The FES-I assesses a person's concerns about falling when performing a particular activity, which consists of 16 questions related to everyday activities. The scores ranged from 16-64 with higher scores indicating a greater fear of falling.

Walking ability

The 10-meter walk test (10MWT) [17] was used to examine the patients' functional mobility. Participants were asked to walk straight along the 14 meter walkway at their fastest walking pace. The initial 2 meters and the final 2 meters of the walkway were used for acceleration and deceleration. Only the time spent in the middle 10 meters was recorded.

Activities of daily living

The Frenchay Activity Index (FAI) [18] is a measure of the frequency of the performance of activities of daily living (ADL) for stroke patients. It assesses a broad range of activities related to everyday life including three domains of domestic chores, leisure/work, and outdoor activities. The frequency in with which the 15 items are undertaken over the preceding six months is assigned a score of '1' to '4,' where a score of '1' is indicative of the lowest frequency of activity. The scale provides a total score of '16' to '60.' Here, the highest score corresponds to the highest level of independence and social adaptability.

Statistical analysis

The independent-t test was used to compare age, height, and mass and the Chi-square test was used to compare gender to identify the differences in demographic data between SPs and HCs. The Chi-square test was applied again to compare the two groups in each of the turning indicators (turn time, step, type, and balance). Additionally, the Pearson's correlation test examined the relationship between turning indicators and outcome measurements (TIS, CMSA-leg, CMSA-foot, BBS, FES-I, 10MWT, and FAI). It was determined that a correlation coefficient of $r<0.4$ was weak, 0.4-0.7 was moderate, and >0.7 was strong [19]. The software SPSS (Version 19.0, Armonk, NY: IBM Corporation) was used for all statistical analysis with a significance of $p<0.05$.

Results

Data were collected from 30 SPs and 30 HCs. The participants in each group were similar in age and height but differed in mass ($p<0.001$) and gender ($p<0.001$) (**Table 1**). There were significant differences between SPs and HCs in turn time ($p<0.001$), number of steps taken ($p<0.001$), strategy ($p<0.001$), and balance ($p<0.001$) (**Table 2**). A moderate correlation was found between turn time and balance and all the measurements except FES-I and FAI. For p and r values see **Table 3**. The number of steps taken and strategy were not correlated with any other measurement.

Table 1 Demographic data of stroke patients and healthy controls. Values are presented as mean ± standard deviation. 10MWT: 10-meter Walk Test; CMSA: Chedoke-McMaster Stroke Assessment Inventory; BBS: Berg Balance Scale; FAI: Frenchay Activity Index; FES-I: Falls Efficacy Scale International; HC: Healthy controls; SP: Stroke participants; TIS: Trunk Impairment Scale. *Significant differences between groups ($p<0.05$).

	SP (N=30)	HC (N=30)
Age (years)	58 ± 11	54 ± 24
Gender (n)*		
Male	20 (67%)	5 (17%)
Female	10 (33%)	25 (83%)
Height (cm)	164 ± 9	160 ± 8
Mass (kg)*	70 ± 18	55 ± 9
Diagnosis (n)		
Infarction	18 (60%)	
Hemorrhage	12 (40%)	
Post-stroke duration (months)	33 ± 32	
Paretic side (n)		
Left	19 (63%)	
Right	11 (37%)	
TIS (score)	18 ± 3	
CMSA (stage)		
Leg	5 ± 1	
Foot	4 ± 2	
BBS (score)	47 ± 7	
FES-I (score)	27 ± 11	
10MWT (sec)	18 ± 15	
FAI (score)	22 ± 7	

Table 2 The percentage of occurrence in each category for all indicators. HC: Healthy controls; SP: Stroke participants; **Significant differences between groups (p<0.05).

Indicators	Category		SP (N=30)	HC (N=30)
Turn time**	0	<2.5 sec	9 (30%)	30 (100%)
	1	2.5 to 2.9 sec	5 (17%)	0
	2	3 sec or more	16 (53%)	0
Turn step**	0	1-2 steps	0	15 (50%)
	1	3-4 steps	13 (43%)	15 (50%)
	2	5 steps or more	17 (57%)	0
Turn strategy**	0	Pivot type	0	22 (73%)
	1	Mixed type	9 (30%)	8 (27%)
	2	Steps type	21 (70%)	0
Turn balance**	0	No loss of balance	9 (30%)	28 (93%)
	1	Lose balance, self-corrects without assistance	14 (47%)	2 (7%)
	2	Lose balance, requires guarding/assistance to prevent fall	7 (23%)	0

Table 3 Correlation of turning indicators and measurements in stroke participants. 10MWT: 10-meter Walk Test; CMSA: Chedoke-McMaster Stroke Assessment Inventory; BBS: Berg Balance Scale; FAI: Frenchay Activity Index; FES-I: Falls Efficacy Scale International; TIS: Trunk Impairment Scale; * Significant correlation between turning indicator and measurement (p<0.05); **Significant correlation between turning indicator and measurement (p<0.001).

	Turning indicators							
	Turn time		Turn step		Turn strategy		Turn balance	
	r value	p value	r value	p value	r value	p value	r value	p value
TIS	-0.42*	0.038	-0.31	0.128	-0.31	0.128	-0.27	0.191
CMSA-Leg	-0.38	0.059	-0.39	0.058	-0.39	0.058	0.57*	0.003
CMSA-foot	0.48*	0.015	-0.37	0.072	-0.37	0.072	-0.33	0.113
BBS	0.53*	0.007	-0.24	0.25	-0.24	0.25	0.61**	0.001
FES-I	-0.01	0.961	0.1	0.655	0.1	0.655	-0.003	0.987
10MWT	0.67**	<0.001	0.17	0.409	0.17	0.409	0.60**	0.001
FAI	0.07	0.747	0.01	0.976	0.01	0.976	-0.33	0.118

Discussion

The principal findings of the study were that the majority of SPs experienced turning difficulties. These subjects took more than three seconds to turn, at least five turn steps, employing an ineffective step strategy, and demonstrated a greater degree of imbalance compared to HCs. A patient's turning performance following a stroke was associated with the degree of motor recovery in the paretic lower limbs, trunk control function, balance, and walking ability, but not correlated to concerns about falling during the performance of ADL.

Previous studies reported that SPs needed more time and a greater number of steps to complete turns compared to HCs [3-6] and, therefore, determined that SPs experience turning difficulty. SPs may also have demonstrated inferior turning performance due to their impaired posture and movements caused by hemiparesis. According to Thigpen et al., turning difficulty should be defined by (1) the presence of staggering during the turn, (2) the absence of pivoting during the turn, (3) the use of 5 or more steps or shifts in weight to accomplish the turn, and (4) a turn duration of 3 seconds or more [7]. Therefore, based on these four indicators, more than half of participating SPs were determined to experience turning difficulty in terms of turn time (53%), number of steps taken

(57%), strategy (100%), and balance (70%). Not all SPs demonstrated turning difficulty, and some performed turns on par with HCs.

All HCs took less than 2.5 seconds to complete each turn compared to the nearly 70% of SPs who required more than 2.5 seconds. All HCs took less than four steps. By contrast, 60% of SPs took at least five steps, and none used one or two steps to complete each turn. Using a greater number of steps and additional time to accomplish a turn could be a compensatory or adaptive strategy to maintain stability during a turn. In terms of strategy, the HCs primarily used the pivot strategy while the SPs primarily adopted the stepping strategy to complete a turn. The pivot is a fast, open-looped movement and feed-forward strategy. The stepping strategy is a slower, closed-looped movement that appeared to increase feedback requirements. Individuals with stroke tended to sacrifice the effective turn strategy to achieve greater stability. Thigpen et al. surmised that the absence of a ballistic pivot was a possible early indicator of underlying problems associated with difficulty in turning [7]. People experiencing turning difficulty tended to take simpler, shorter, and slower steps to compensate for the loss of motor coordination [20]. Moreover, nearly all HCs turned without losing balance, but the majority of SPs displayed instability during each turn. Further analysis indicated that 12 of the 30 SPs (40%) in the current study met all indicators of turning difficulty. The authors believe that those SPs suffered from turning difficulty because they presented instability during each turn despite having adopted a compensatory strategy.

Turning difficulty following a stroke was moderately correlated with motor recovery of lower limbs, trunk control function, and balance and walking ability, which was in alignment with the previous studies [5,8,9,21]. Turning is a series of foot movements leading the body toward a new direction. Motor recovery in the paretic leg and foot are, therefore, crucial to turning performance. During turns, the inner and outer legs play different roles with the inner leg stabilizing the posture and the outer leg providing propulsion and swing to realign the body in the new direction [22]. However, the paretic leg lacked ankle stability when used as the inner leg and presented poor ground clearance when serving as the outer leg [23]. Stated simply, the paretic leg was unable to achieve effective function during the turn whether it worked as the inner or outer leg.

Only one study conducted by Kobayashi et al. investigated the correlation of walking turns throughout 180°C and trunk control. The study found that as the patient's Functional Assessment for Control of Trunk (FAC) score declined, the more turn time and a greater number of steps were required [8]. This indicated that walking turns required trunk stability. Impaired trunk control affects not only proximal control of the body but also the movement of the distal limbs. Trunk control plays an important role in upright, stability, and inter-segmental coordination during sitting, standing, and walking [10,11]. Thus, trunk control function could also be a contributing factor to turning difficulty.

Static balance is the ability to maintain postural stability with the center of gravity (COG) within the base of support (BOS) in a fixed posture. Dynamic balance is more challenging, referring to the ability to transfer the COG around the BOS [24]. Turning is a dynamic movement which requires stability for fluidity and safety. However, balance dysfunction was commonly observed in stroke patients due to muscle weakness, abnormal muscle tone, impaired motor recovery, and poor weight shifting. Balance dysfunction itself could lead to turning difficulty. Additionally, turning was more closely correlated with walking capacity in comparison to other measures. Kobayashi et al. indicated that standing turn time could be useful for distinguishing community ambulators from independent ambulators [8]. Making a turn may be more challenging than linear walking because it requires greater degrees of balance maintenance and limb coordination [25,26].

It is interesting to note that turning performance did not correlate with FES-I and FAI. The FES-I required participants to rate their concerns about falling during everyday activities, and the FAI required subjects to rate the frequency in which they performed activities related to daily life. Therefore, the participants' perceived ability may not have a strong association with the physical performance of turning. Turning was evaluated in the secure indoor laboratory in contrast to the everyday environment of the FES-I and FAI, which may be another reason for this disassociation. The results were in line with the study conducted by Robinson and Ng that found no correlation between 180°C turn time and the level of confidence in balance as measured by the Activities-specific Balance Confidence (ABC) scale in stroke patients [21]. Additionally, the number of turn steps and the strategy employed were not correlated with any measurements. There are two possible explanations. First, physical impairments and balance and walking ability did not affect the number of turn steps and the adoption of a particular strategy. Second, the turn step number and strategy indicators may have floor effects because all SPs placed in the two worst performing categories.

In terms of demographic data, both groups were similar in age and height but differed in mass and gender. According to epidemiological studies, the number of males that suffer from stroke is greater than females of comparable age, and males are generally heavier than females in the adult population [27,28]. It was therefore reasonable to include a greater percentage of males and corresponding increase in bodyweight in the SP group.

There are some limitations to this study. The results of the current study could only be generalized to high-functioning stroke patients because our participants retained good cognition and communication abilities. Their motor stages of leg and foot were five and four respectively, indicating moderate motor recovery with synergy decreased and selective movements presented [13]. A BBS score above 41 indicates a low fall risk [15]. A walking velocity of more than 0.45 m/s represents community ambulation [29]. Therefore, an investigation of turning in low-functioning stroke patients is needed with a larger sample population.

Conclusion

In conclusion, the main findings of the study were that more than half of stroke patients required more than 3 seconds to turn, took at least five steps per turn, employed an ineffective step strategy, and demonstrated greater instability than healthy adults during 180° on-the-spot turns. All of these factors indicated turning difficulty. Their turning performance was moderately associated with the degree of motor recovery of the paretic lower limbs, trunk control, and balance and walking ability. However, performance was not correlated with concerns about falling during activities of daily living. Thus, it can be expected that the majority of stroke survivors may experience turning difficulty. This is particularly true for those with poor motor recovery, trunk control, and balance and walking capacity. The evaluations described in this paper can assist health care professionals to identify turning difficulty and apply the necessary interventions to facilitate recovery.

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