



Original Article

180° turn while walking: characterization and comparisons between subjects with and without stroke

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Abstract. [Purpose] Limitations in performing the 180°-turning increase the risk of falls and disabilities in stroke patients. The aim of this study was to characterize and compare the 180°-turning between people with and without stroke, considering the direction towards which they turned. [Subjects and Methods] Fourteen subjects with stroke and 14 matched healthy controls performed the 180°-turning twice while walking: towards the self-selected, and the opposite directions. The turning performances were recorded using three video cameras. The videos were randomly analyzed by a single examiner, who characterized the turning, while considering the time required to complete the task, the number of steps, balance, and turning type. Friedman Tests and ANOVA (2 × 2) were used to compare the groups and turning direction factors (turning towards the self-selected versus opposite sides, and towards the paretic/non-dominant versus non-paretic/dominant sides). [Results] No interaction between the groups and turning directions, and no significant differences between the turning directions were found. However, significant differences were found between the groups for all variables used to characterize the turning performance, except for the type of turning. [Conclusion] Stroke subjects demonstrated poor performance on the 180°-turning, regardless of the turning direction. Duration, number of steps, and balance loss indicated difficulties in turn performance.

Key words: Stroke, Activities of daily living, Turning

(This article was submitted Sep. 1, 2016, and was accepted Oct. 21, 2016)

INTRODUCTION

Motor impairments, such as hemiparesis, are very common after stroke and are associated with reduced mobility¹⁻³). A primary goal of rehabilitation interventions for subjects with stroke is regaining mobility^{1, 5}), which is an important component of functioning and health^{1, 4-6}). It is well recognized that changes in gait performance are the greatest contributors to post-stroke disabilities³). The degree to which gait performance is altered following a stroke is related to the severity of motor impairments of the lower limbs⁷) and to the degree to which community-dwelling subjects are functionally independent⁸). Furthermore, walking is the activity that subjects with stroke rate as being the most important⁹).

Of the 10 walking steps commonly used in activities of daily living, two are used for turning. The majority of turns performed while walking range from 166 to 210 degrees¹⁰). This turning magnitude requires complex changes in gait patterns, which could provide evidence of mobility impairments¹¹). Moreover, turning is usually used to change directions due to obstacles or to re-direct gait trajectories, according to the subjects' needs¹²⁻¹⁴). Therefore, the ability to perform turning is a determining factor for safe ambulation and functional independence¹⁵⁻¹⁷).

In the elderly and in individuals with Parkinson's disease, difficulties in performing turning have been associated with

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limitations in activities of daily living^{14, 18–21}). In elderly subjects, impaired turning has been associated with increased risks of falls¹⁷). Injuries due to falls during turnings are eight times more common than during straight forward walking²²).

An important feature observed in subjects with hemiparesis due to stroke is gait asymmetry^{7–9}). Asymmetric gait patterns may potentiate the difficulties demonstrated during turning^{23, 24}). Differences exist in the incidence of falls during turning, when it is performed towards different sides. According to Hyndman et al.¹⁶), most falls in subjects with stroke result when they turn towards their paretic side. However, previous studies which compared the turning characteristics of subjects with stroke did not find any differences between turning towards the paretic and non-paretic sides, when the time^{23, 25, 26}) and the oscillations of the center of mass²⁵) were considered. It is possible that differences between turning performances towards the paretic and non-paretic sides could be related to other variables, such as balance and number of steps. A more detailed investigation may show characteristics that illustrate the difficulties that the subjects with hemiparesis have to perform the turning²¹).

Therefore, the aims of this study were: (a) to characterize the 180° turns while walking in subjects with hemiparesis due to stroke and in matched-healthy control subjects, considering the directions towards which the turning was performed (preferred versus non-preferred sides and paretic versus non-paretic sides); and (b) to compare the groups regarding the directions towards which the turning was performed.

SUBJECTS AND METHODS

Stroke subjects were recruited from the general community by contacting physical therapists and screening out-patient clinics at university hospitals in the city of Belo Horizonte, Brazil. Patients included were ≥ 20 years of age; demonstrated no receptive aphasia; had residual weakness and/or increased tonus of the paretic lower limb muscles^{27, 28}); and were able to perform the Timed “Up and Go” (TUG) test, with or without assistive devices. The healthy control subjects, without stroke-related disabilities or other neurologic, orthopedic, or unstable cardiac conditions, were matched to the subjects with stroke, by age and gender.

Demographic and clinical data were collected to document the age, gender, dominant leg, paretic side, and time since the onset of the stroke by trained physical therapists, for characterization purposes. Before the data collection, eligible participants were informed about the objectives of the study and were asked to provide consent, based upon previous approval from the University research ethical review board.

The performance of the 180° turn while walking was assessed during the TUG test²⁹), which is the most used and recommended test to assess basic functional mobility³⁰). The TUG test has shown good values of validity²⁹) and reliability^{31–33}) in subjects with stroke, and it is a feasible test^{29, 30}). Furthermore, the TUG test has already been used to assess turning performances^{18, 21, 26, 34, 35}).

To perform the TUG test, subjects sat on a chair (depth of 45 cm, width of 49 cm, and arm rest height of 20 cm), whose height was adjusted to 100% of their leg length, determined as the distance from the lateral femoral condyle to the ground^{36, 37}). The backrest was adjusted to a trunk position at approximately 90°³⁸). Subjects were instructed to sit comfortably with their backs against the chair, and on the word “go”, stand up, walk at their self-selected comfortable speeds for three meters, turn around, return, and sit down²⁹).

After two familiarization trials, in which the turning was performed towards both sides, the subjects were first instructed to perform the TUG with the turning towards their preferred side, and after a 1-min rest interval, they were instructed to perform a second trial turning towards the opposite side. Therefore, all subjects performed turns towards both directions, which were considered for the analyses. During the test, the examiner stood by the subjects’ sides. If there was a risk of falling, the examiner followed the subjects a half-step behind, so as not to determine their walking pace³²).

Three video cameras (*Sony DCR-DVD408*[®]) were used to record the TUG performances. They were positioned on the front, left, and right sides of the subjects and allowed acquisition frequencies of 30 Hz. Only one TUG trial for each turning direction was recorded, as was previously adopted²⁶) and recently recommended³¹).

The three recorded video images were processed and synchronized using the *VirtualDube*[®] software, following procedures which already have been demonstrated to be reliable and precise³¹). Then, the three processed videos were grouped into the same file by the *Adobe® After Effects CS3*[®] software, so that all three images of the same subject could be simultaneously analyzed on the same video screen. To avoid biases related to memory, masking effects on the subjects’ faces were included in the videos.

All of the recorded and processed TUG trial videos were randomly analyzed by a second examiner, who was a physical therapist. The videos were analyzed using video resources provided by the *VirtualDube*[®] software, such as frame-by-frame slow motion, stop, and zoom functions. The analyses were organized according to the turning directions and considered: (a) turning towards the preferred versus non-preferred sides of both stroke and control groups; and (b) turning towards the paretic side of subjects with stroke matched with the non-dominant side of the control subjects, as well as turning towards the non-paretic side of the subjects with stroke matched with the dominant side of the control subjects.

Initially, the examiner determined the beginning and the end of the 180° turning for each subject, following previously described criteria^{18, 21}). Then, the turning was characterized according to methodology described by Thigpen et al.²¹) The time to accomplish the turning, the number of steps, balance, and type of turning were observed. These parameters were reported considering the following categorical variables, ranging from 1 to 3:

Table 1. Demographic and clinical characteristics of the participants and the statistical results* of the comparisons between the stroke (n=14) and matched healthy subjects (n=14)

VARIABLE	Stroke	Healthy
Age (years), mean \pm SD	58.9 \pm 10.2	60.9 \pm 10.4
Gender (male/female)	10/4	10/4
Time since the onset of stroke (months), mean \pm SD	90.1 \pm 36.5	–
Paretic side (right)	8	–
Timed “Up and Go” (seconds), mean \pm SD	18.2 \pm 8.0	9.3 \pm 1.5*

SD: standard deviation

* $p < 0.01$

a) *Time to accomplish the turning*: 1) “less than 2.50 seconds”; 2) “between 2.50 and 2.99 seconds”; 3) “3.0 seconds or more”. The time to accomplish the turn was also analyzed considering the total absolute values, in seconds²¹.

b) *Number of steps*: 1) “Accomplishes complete reversal of direction with 1 to 2 steps”; 2) “Accomplishes complete reversal of direction with 3 to 4 steps”; 3) “Accomplishes complete reversal of direction with 5 steps or more”²¹.

c) *Balance during turning: loss of balance defined as “staggering, a partial loss of balance in any turning direction”*: 1) “No loss of balance”; 2) “Loss of balance, self-correction without assistance”; 3) “Loss of balance, requires assistance to correct or prevent fall”²¹.

d) *Type of turn: type of strategy used to accomplish the reversal of direction*: 1) “Pivot: The body rotates/spins 180° as a bloc unit over the foot (or feet) in one controlled, discrete movement. The foot (or feet) acts as a pivot point about, which the body spins 180°”; 2) “Mixed: The 180° turn is accomplished by partial rotations or spinning mixed with steps or weight shifts were no pivoting occurs. A mixture of steps and pivot movements occurs”; 3) “Steps: The 180° turn is accomplished with no evidence of pivoting or spinning; the turn is accomplished through a series of steps or weight shifts”²¹.

All statistical analyses were carried out using the SPSS® for Windows® (version 15.0) software. Descriptive statistics and tests for normality (Shapiro-Wilk) were performed for all variables. *Friedman* tests (categorical variables) and ANOVA 2×2 (total time in absolute values) were used to compare the groups (stroke and matched-healthy controls) and turning directions (towards the preferred versus non-preferred and towards the paretic/matched versus non-paretic/matched sides) with a significance level of $\alpha < 0.05$.

RESULTS

Fourteen subjects with hemiparesis, 10 males and four females, with a mean age of 58.9 ± 10.2 years, ranging from 46 to 79 years, comprised the stroke group. The control group included 14 healthy control subjects, matched by age and gender. The groups were similar regarding age ($p=0.80$) and gender ($p=1.0$). Subjects with stroke spent more time completing the TUG test, than matched healthy subjects ($p < 0.001$) (Table 1).

For all variables that were investigated to characterize turning performance, no interactions were found between the groups and turning directions (preferred versus non-preferred and paretic/non-dominant side versus non paretic/dominant side ($0.18 < F < 3.29$; $0.081 < p < 0.668$) (Table 2). Significant between-group differences were found regarding the time required to complete the turning for both categorical ($F=42.89$; $p < 0.001$) (Table 2) and absolute variables (time, in seconds) ($F=18.54$; $p < 0.001$). The subjects with stroke spent more time to accomplish the turning, than the healthy controls (4.3 ± 1.7 s vs. 2.1 ± 0.4 s, respectively).

Significant between-group differences were also found regarding the number of steps required to complete the turning ($F=16.31$; $p < 0.001$). Subjects with stroke used more steps (4.8 ± 1.3 steps), than the healthy controls (3.2 ± 0.7 steps). In addition, none of the subjects were able to perform the turning with one or two steps (Table 2). No significant between-group differences were found regarding the type of turning ($F=0.16$; $p=0.689$). Both subjects with stroke and healthy controls used mainly the “step” type to complete the turning (Table 2).

Significant differences between the groups were found regarding the loss of balance during turning toward the preferred versus non-preferred sides and toward the paretic/matched versus non-paretic/matched sides ($F=8.27$; $p=0.008$). Subjects with stroke showed higher frequency of loss of balance, than that of healthy control subjects (Table 2).

For all analyzed variables, no significant differences were found between the turning directions. Turning toward the self-selected side was similar to that toward the opposite side ($0.18 \leq F \leq 1.80$; $0.19 \leq p \leq 0.668$) and turning toward the non-paretic/matched side was similar to that toward the paretic matched side ($0.18 \leq F \leq 1.46$; $0.237 \leq p \leq 0.668$) (Table 2).

DISCUSSION

The results of the present study indicated that subjects with hemiparesis due to stroke spent more time, used a greater number of steps, and showed higher frequencies of balance loss, when compared to matched-healthy control subjects, regardless of the direction towards which they turned. Both groups were similar regarding the strategy used to complete the turns,

Table 2. Number of subjects in each category, considering the turning directions analyzes: (a) turning towards the preferred (1st trial) versus non-preferred side (2nd trial) of both stroke and healthy control groups; and (b) turning towards the paretic side of subjects with stroke matched with towards the non-dominant side of the controls versus towards the non-paretic side of subjects with stroke matched with the turning towards the dominant side of the healthy control subjects.

Variables		Stroke group				Control group			
		1st trial	2nd trial	Paretic	Non-paretic	1st trial	2nd trial	Non-dominant	Dominant
Number of steps*	1–2	0	0	0	0	2	2	2	2
	3–4	7	9	7	9	12	12	12	12
	5 or more	7	5	7	5	0	0	0	0
Turning time*	<2,50s	1	2	1	2	11	13	12	12
	2.50–2.99s	3	4	2	3	0	2	1	3
	3s or more	10	9	9	10	0	1	0	1
Turning type	Pivot	1	1	0	2	1	1	1	1
	Mixed	0	1	0	1	3	0	2	1
	Steps	13	12	14	11	10	13	11	12
Balance*	No loss of balance	11	10	11	10	14	14	14	14
	Loss of balance, but self-corrects without assistance	3	4	3	4	0	0	0	0
	Loss of balance, requires assistance to correct or prevent fall	0	0	0	0	0	0	0	0

*p<0.05 only for the between groups comparisons

since both groups used the same “step” type strategy.

Few studies were found that analyzed turning performances in subjects with stroke^{13, 23, 25, 26}), despite the significant associations between turning and the incidence of falls¹⁶) and its importance for functional mobility^{10, 15–17}). Analyses of turning performances have focused primarily on elderly subjects^{10, 21}) and individuals with Parkinson’s disease^{14, 20}). In elderly subjects, risks of falls were associated with turning difficulties, demonstrated by greater number of steps and loss of balance^{18, 21}). Thus, these previous results demonstrated that individuals, who had difficulties in performing turns, were more unstable²¹). Similar results were found in the present study; subjects with hemiparesis due to stroke also used a greater number of steps, had more frequent losses of balance, and spent more time to accomplish the turns, when compared to healthy control subjects. Therefore, it is possible to conclude that subjects with hemiparesis due to stroke demonstrate difficulties in performing turns while walking.

Slow speeds and decreased step length are typical features of stroke gait^{39, 40}). The present study analyzed turning performances while walking and these typical characteristics were also observed. Another possible explanation for the greater number of steps during turning could be the increased frequency of balance loss, which was also observed in the subjects with stroke. Thus, using a greater number of steps could be a way to compensate for balance deficits²⁶). Lam et al.²³) applied the time and the number of steps to complete the turns as parameters of functional capacity. They observed that more time and a greater number of steps were indicative of lower functional capacity. By applying the same criteria, the findings of the present study showed that the subjects with stroke not only had more difficulties in accomplishing turns when compared to matched-healthy control subjects, but also had lower functional capacities.

Low functional capacity, difficulties in performing turns, and fear of falling may provide some explanations for the fact that subjects with stroke avoid performing 180°-turns during their daily living activities^{13, 23, 26}). This could result in decreased mobility and increased functional restrictions¹⁵), contributing to the observed higher frequency of balance loss. Considering that balance is a very complex skill related to the interactions of sensorimotor processes, environmental, and biomechanical factors¹³), which were not investigated in the present study, different individuals could demonstrate balance deficits in accordance with deficits in a combination of these factors⁴¹). Thus, future studies should investigate factors associated with balance in subjects with stroke during turning activities.

Despite the differences between subjects with and without stroke regarding their turning performances for the most investigated variables (number of steps, time and frequency of balance loss), both groups used mainly the “step” type of turning. This is probably because this strategy was easier and provided more stability during movement for both groups. “Pivot” turning is a fast, open-looped movement, which requires feed-forward mechanisms, whereas “step” type turning is a slower, more closed-looped movement, and appeared to increase feedback requirements^{14, 21}). Thus, healthy subjects could use “step” turning as their preferred type of turning to facilitate changes in directions to accomplish the turn safely and quickly. In the same way, subjects with stroke could also prefer the “step” type to increase safety and reduce loss of balance and fear of falling.

Considering the typical features of hemiparesis^{1, 2, 7–9}), it was expected to find differences in the evaluated turning parameters between the directions towards which the subjects with stroke turned (i.e., paretic and non-paretic). However, as was observed in healthy subjects, no differences were found for any investigated parameter regarding the directions towards

which the subjects turned, as also previously reported^{23, 25}). A possible explanation for these findings is that the motor impairments, also observed when turning towards the non-paretic side⁴²), could be enough to compromise the performance in functional activities, such as 180° turns towards the non-paretic side. Thus, the capacity to perform activities of daily living, such as turning after stroke, depends not only on the severity of the neurologic deficits, but also on the individual's exercise capacity^{43–45}). Hemiparesis affects the persons' abilities to engage in physical activity, and a sedentary lifestyle increases skeletal muscle mass loss in both the paretic and non-paretic sides. These changes have implications for strength and functional ability⁴⁶). Therefore, it is possible that the motor impairments observed in both lower limbs of subjects with stroke could be related to the similarity in difficulties in performing the turns towards the paretic and non-paretic sides.

Finally, fear of falling has been cited as another possible explanation for the similarity between the sides, when turning characteristics were compared between the paretic and non-paretic sides²⁶). Due to the fear of falling, subjects with stroke could purposely reduce the speed, when turning towards their non-paretic side, and, therefore, their turning performance towards the non-paretic side became similar to that of the paretic side.

The differences observed in the turning performances between subjects with stroke and healthy controls (time required to complete the turns, number of steps, and balance loss) and similarity (type of turning) contributed for a more detailed knowledge of aspects that hindered this activity. These findings may be useful for the identification of subjects who have difficulty in performing turns. Therefore, these variables should be considered during rehabilitation interventions aimed at improving turning performances and mobility of subjects with stroke.

Some important limitations of the present study should be taken into consideration in the interpretation of these results. First, the number of variables used to analyze the 180° turns restricts generalizations related to the indicators of difficulty in the turning performances: troubles in turning could also be related to biomechanical and sensory impairments, variables that were not analyzed in the present study. These variables should be considered in future studies. Another limitation was the sample size. A larger sample of the population of subjects with hemiparesis due to stroke would be more representative and would allow greater generalization of the results. Finally, the design of the present study does not allow for temporal relationships between the investigated variables. Therefore, causal inferences cannot be established.

In conclusion, the findings of the present study suggested that subjects with hemiparesis due to stroke demonstrated worse performance in 180° turns while walking, when compared to healthy control subjects, regardless of the turning directions. Subjects with stroke spent more time, required a greater number of steps, and showed a higher frequency of balance losses. Only the type of turning was similar between subjects: both groups used mainly the “step” type movement to complete the turns.

ACKNOWLEDGMENTS

The authors are thankful to the Brazilian Government Funding Agencies (CAPES, CNPq, FAPEMIG, and PRPg/UFGM), Graduate Students' Exchange Program (GSEP-Commonwealth Scholarship Program; CCSP), Government of Canada Awards (CGA), and International Society of Biomechanics (ISB) for their financial support.

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