Strategies to adapt walking mechanics to path curvature after a stroke

Karine Duval[1,2], MSc, Tim Inglis[1,2], PhD, Janice Eng[1,3], PhD, Tania Lam[1,2], PhD

[1]University of British Columbia, International Collaboration on Repair Discoveries, Vancouver, BC

[2]University of British Columbia, School of Kinesiology, Vancouver, BC

[3]GF Strong Rehabilitation Center, Department of Physical Therapy, UBC, Vancouver, BC

1. Introduction

One of the most obvious challenge after a stroke is daily mobility. Since up to 45% of all steps taken daily involve some form of turning, difficulty turning while walking contributes to the decreased level of independent walking and may explain the higher incidence of falls in stroke survivors.

Aim: Describe how people with stroke adapt their walking mechanics to path curvature by measuring whole-body center of mass and kinematic data.

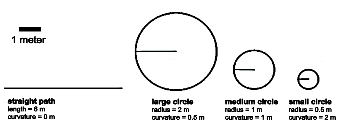
2. Methods

Eleven stroke participants (8 males, 3 females) and 11 age-matched able-bodied individuals (4 males, 7 females) participated in this study.

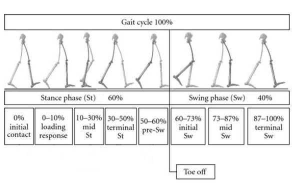
participant	age (years)	time since stroke (years)	affected side	type of stroke	location of stroke	Chedoke McMaster score	
						leg	foot
control	58.0						
stroke							
1	37	5	left	ischemic	MCA territory	5	3
2	73	5	left	ischemic	MCA territory	3	3
3	73	4	right	hemorrhagic	brainstem	4	3
4	59	11	right	hemorrhagic	brainstem	3	2
5	71	3	left	ischemic	paramedian pontine	5	5
6	58	5	left	hemorrhagic	basal ganglia	3	2
7	88	11	left	ischemic	MCA territory	3	3
8	64	23	right	hemorrhagic	MCA territory	3	2
9	77	11	left	ischemic	MCA territory	3	3
10	52	5	right	hemorrhagic	intracerebral	5	4
11	55	11	right	ischemic	subcortical	3	2

Participants walked along four paths, illustrated below, at their preferred walking speed while kinematic data were collected. The control group matched the walking speed of the stroke group.

Data were divided to analyze the walking mechanics of the inside leg of the turn separate from the outside leg.



The gait cycle was divided into the following phases:



Whole-body center of mass was calculated during midstance and was normalized as a percentage of step-length and step-width.

Kinematic data were normalized to the straight walking trial for each participant.

3. Results: Whole-Body Center of Mass

A. How is whole-body center of mass adapted to path curvature?

Figure 1: Position of the center of mass when A. the foot is on the inside of the turn and B. the foot is on the outside of the turn. Straight walking is represented by the largest circle followed by large (curvature = 0.5 m), medium (curvature =1.0 m) and small (curvature = 2.0 m) paths.

Figure 1A: Foot on the inside of the turn **Figure 1B: Foot on the outside of the turn**

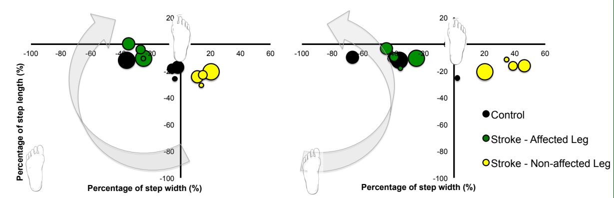
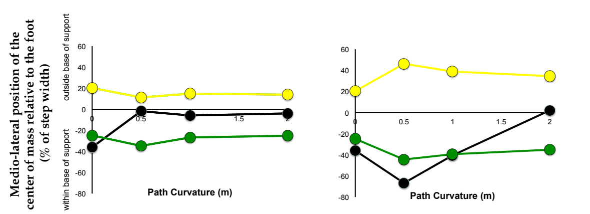


Figure 2: Changes in the medio-lateral position of the whole-body center of mass with increasing path curvature. A positive value means the center of mass is outside the base of support and a negative value means the center of mass is within the base of support (between the two feet).

Figure 2A: Foot on the inside of the turn **Figure 2B: Foot on the outside of the turn**



Summary: The center of mass of the control group remained within the base of support. The stroke group's center of mass was outside of the base of support when the non-affected leg was in midstance. This lean increased with increasing path curvature. When the affected limb was in midstance, the center of mass remained within the base of support.

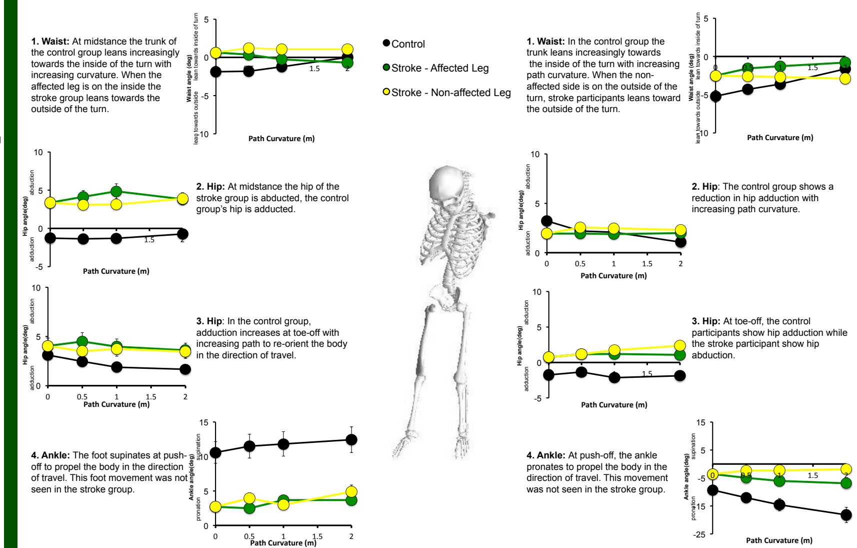
4. Results: Joint Kinematics

B. How are center of mass adaptations to path curvature reflected in joint kinematics?

Mean angles in the frontal planes were calculated for each phase of the gait cycle. Movement at the waist, hip and ankle can help illustrate the differences in the mechanics of curved walking between the control and the stroke groups. Mean angle for specified phases of the gait cycle were graphed relative to path curvature.

Figure 3: Differences in the modulation of joint movement to path curvature between the control and the stroke participants. This figure compares the dominant leg of the controls to the affected leg of the strokes.

Figure 3A: Foot on the inside of the turn **Figure 3B: Foot on the outside of the turn**



Summary: When the stroke group walked with their affected leg on the inside of the turn, they leaned towards the leg on the outside of the turn. Once the affected side was in swing phase they rotated their pelvis to re-orient their body in the direction of travel. When turning with their non-affected side on the inside of the turn, they leaned to the inside and rotated their body during stance of the inside leg. Unlike the stroke group, the control group are able to use their ankles to push-off and orient the body in the direction of travel.

5. Conclusion

Curved walking in the able-bodied group required rotating the upper body over the leg located on the inside of the turn. This strategy was not seen in the stroke group who avoided spending time on their affected leg irrespective of whether it was on the inside or outside of the turn. The stroke group leaned outside of their base of support to navigate the paths when their non-affected leg was in midstance, likely compromising their balance by moving their center of mass outside of their base of support.

The findings of this study support that more time be spent on advanced gait skills such as walking when designing a rehabilitation program. The demands of curved walking are clearly different than straight walking and the specific requirements for successful curved walking should be addressed to ensure independent ambulation.

Contact information: kduval.ubc@gmail.com