STRENGTH AND AEROBIC DEMANDS OF DIFFERENT STAIR-STEPPING STRATEGIES IN PERSONS WITH CHRONIC STROKE

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INTRODUCTION

Stroke is the most common neurological disability affecting Canadian adults. Nearly all survivors of mild stroke and 85% of survivors of moderate to severe stroke return to living in the community [1]; however, independence is often compromised. Performance limitations of more challenging physical activities such as stair negotiation; an important task for community access, is of concern. Healthy older adults consider stair negotiation as one of the most challenging physical tasks attributed to aging [2]. It follows that for people with mobility deficits attributable to stroke, the task would be even more challenging and may introduce compensatory strategies. A "step-by-step" (SBS) pattern of stair negotiation, where both feet land on each step, may be adopted to enhance stability and/or to off-load the affected or weak limb in lieu of the traditional "step-over-step" (SOS) method (where one foot lands on each step). To date, the strength and aerobic demands of stair negotiation are not well described in the chronic stroke population, and little is known about the differences in physical requirements associated with different stair-stepping patterns.

The primary objective of this ongoing study is to determine the relative strength and aerobic requirements (or costs) of SBS and SOS stair ascent and descent in persons with chronic stroke compared to their healthy age-matched counterparts.

METHODS

Ten people with unilateral, hemispheric stroke ($\geq$ 6 months post-stroke) and ten healthy age- and sex-matched older adults were recruited from the community (Kingston, Ontario) to participate in the study. Peak joint moments produced at the ankle, knee and hip of the paretic and non-paretic limbs in the stroke population, and the dominant limb in the control population were measured during stair ascent and descent (at self-selected speeds) using an inverse dynamics approach (Visual 3D, C-Motion, Inc., Germantown, MD). A custom-designed 4-step staircase, with a force plate (AMTI, Newton, MA) replacing the second step, and opto-electric cameras tracking infra-red emitting diodes (IREDs) placed on the lower limbs were used. Peak moments created during stair ascent and descent were expressed as a ratio of the corresponding maximum isometric torque, measured by dynamometer (Biodex, System 3, Shirley, NY) to provide an estimation of the relative strength cost.

For the SBS method, stroke participants always led with their unaffected limb, and control participants led with their dominant limb. All participants were asked perform trials without the use of a handrail as well as with handrail use (unaffected (stroke) or dominant (control) hand).
Oxygen consumption and heart rate were collected during ascent and descent of a full flight of stairs (15 steps) using a metabolic unit (CosMed K4b2, Chicago, IL). Peak oxygen consumption measured during the task was expressed as a ratio of the estimated maximal oxygen consumption determined from a submaximal cycle ergometer test to provide an estimate of relative aerobic cost.

Statistical analyses were not performed given the small sample size; means and standard deviations are reported.

RESULTS & DISCUSSION

The participants with stroke 6 males, 4 females) averaged 64.9 $\pm$ 10.1 years of age and their healthy counterparts (6 males, 4 females) were 65.1 $\pm$ 11.2 years of age. Three stroke participants and five control participants were able to ascend and descend the stairs both with and without the use of a handrail; the remainder only completed the handrail condition.

Relative strength was calculated for the affected and unaffected limbs in the stroke group, and the dominant limb in the control group during stair ascent and descent, while performing SBS or SOS stepping strategies with and without the use of a handrail. The findings are reported in Table 1.

In both groups and for both sides in stroke, the relative strength costs tended to be highest at the ankle, followed by the knee then the hip. This reflects the importance of plantarflexor power to accomplish the task. In stroke, a greater proportion of maximal plantarflexor strength was required on the affected side than on the unaffected side for all conditions suggesting that less reserve capacity is available. At the knee and hip, the relative costs were more evenly distributed between sides in stroke even though the affected side was weaker (peak isometric strength 6% - 20% less on the affected side). This may be a strategy used to keep the demands within their physical capabilities [3,4,5].

Within each group, the SOS method was generally more costly in terms of strength requirements than the SBS method at all joints. Handrail use does not appear to have any consistent effect on the strength costs in control subjects, although handrail use does appear to influence the requirements associated with the affected limb in stroke.

The oxygen consumption relative to an estimated maximum oxygen uptake capacity, i.e. oxygen cost during ascent and descent of a single flight of stairs is shown in Table 2. For safety, all participants used the handrail.

Ascent was associated with a higher mean oxygen cost than descent, likely reflecting the primarily positive muscle work required to climb stairs. The stroke group used a higher proportion of their estimated maximum capacity to negotiate stairs compared to healthy controls in all conditions. While the SBS strategy may compensate for limitations in strength in stroke, it is associated with a higher cost than SOS during ascent likely a result of taking twice as many steps to cover the same distance. The trend was not as pronounced in controls.

Table 1 Mean strength cost (peak moment/maximum isometric strength) associated with the affected and unaffected limbs and the dominant limb in different conditions

AFFECTED (STROKE)	**SBS**				**SOS**			
	Handrail		**No Handrail**		**Handrail**		**No Handrail**	
	Ascent	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**
Ankle (Ext)	1.2 ± 0.7	1.3 ± 0.8	0.8 ± 0.3	0.8 ± 0.4	1.5 ± 0.6	1.6 ± 0.7	0.9 ± 0.3	1.1 ± 0.4
Knee (Ext)	0.4 ± 0.3	0.8 ± 0.4	0.2 ± 0.2	0.3 ± 0.1	0.8 ± 0.3	0.9 ± 0.4	0.4 ± 0.2	0.4 ± 0.1
Hip (Flex)	0.3 ± 0.1	0.8 ± 0.9	0.2 ± 0.1	0.3 ± 0.1	0.7 ± 1.0	0.9 ± 0.6	0.2 ± 0.1	0.4 ± 0.2
Hip (Ext)	0.4 ± 0.4	0.5 ± 0.7	0.2 ± 0.1	0.1 ± 0.1	0.4 ± 0.2	0.3 ± 0.3	0.3 ± 0.1	0.1 ± 0.1
UN-AFFECTED (STROKE)	**SBS**				**SOS**			
	Handrail		**No Handrail**		**Handrail**		**No Handrail**	
	Ascent	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**
Ankle (Ext)	0.7 ± 0.4	0.7 ± 0.4	0.5 ± 0.2	0.5 ± 0.1	1.2 ± 0.4	1.3 ± 0.6	0.6 ± 0.2	0.8 ± 0.1
Knee (Ext)	0.7 ± 0.4	0.5 ± 0.3	0.3 ± 0.2	0.3 ± 0.1	0.8 ± 0.3	0.8 ± 0.4	0.5 ± 0.1	0.5 ± 0.1
Hip (Flex)	0.3 ± 0.2	0.7 ± 0.6	0.2 ± 0.1	0.4 ± 0.2	0.3 ± 0.2	0.7 ± 0.5	0.2 ± 0.0	0.6 ± 0.1
Hip (Ext)	0.4 ± 0.4	0.2 ± 0.2	0.3 ± 0.2	0.1 ± 0.1	0.5 ± 0.4	0.2 ± 0.3	0.3 ± 0.3	0.1 ± 0.1
CONTROL	**SBS**				**SOS**			
	Handrail		**No Handrail**		**Handrail**		**No Handrail**	
	Ascent	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**	**Ascent**	**Descent**
Ankle (Ext)	0.9 ± 1.0	0.9 ± 0.8	0.7 ± 0.3	0.8 ± 0.4	1.2 ± 1.9	1.0 ± 1.3	1.3 ± 0.3	1.1 ± 0.3
Knee (Ext)	0.7 ± 0.4	0.5 ± 0.6	0.5 ± 0.2	0.2 ± 0.1	0.6 ± 0.3	0.6 ± 0.2	0.5 ± 0.2	0.5 ± 0.3
Hip (Flex)	0.2 ± 0.1	0.5 ± 0.4	0.2 ± 0.1	0.3 ± 0.2	0.2 ± 0.2	1.0 ± 1.0	0.2 ± 0.1	0.5 ± 0.2
Hip (Ext)	0.2 ± 0.2	0.1 ± 0.2	0.1 ± 0.1	<0.1	0.4 ± 0.2	0.4 ± 0.6	0.3 ± 0.2	0.1 ± <0.1

SBS: Step-by-step; both feet land on the same step; SOS: Step-over-step; one foot lands on each step

Table 2 Mean oxygen consumption relative to estimated maximum uptake in stroke and healthy controls while walking a single flight of stairs using different strategies (n=5 stroke, n=5 control)

	SBS Ascent	**SBS Descent**	**SOS Ascent**	**SOS Descent**
STROKE	0.52 ± 0.18	0.27 ± 0.06	0.38 ± 0.14	0.35 ± 0.15
CONTROL	0.31 ± 0.07	0.21 ± 0.06	0.27 ± 0.06	0.22 ± 0.07

SBS: Step-by-step; both feet land on the same step; SOS: Step-over-step; one foot lands on each step

CONCLUSIONS

These preliminary findings demonstrate asymmetries in the strength demands between the paretic and non-paretic limbs which may limit overall mobility. Our data suggest that while the SBS stair-walking strategy may reduce the strength costs, the consequence of taking twice as many steps to cover the same distance appears to tax the cardio-respiratory system to a greater degree than using a SOS strategy, particularly for stroke survivors.

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