Reach-to-Grasp Co-ordination in the Paretic Limbs of Individuals with Stroke: Insight from a Barrier Paradigm

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Objective: *Reach and grasp components must be co-ordinated to preserve the optimal reach-to-grasp performance. However, conflicting results regarding the deficit in reach-to-grasp co-ordination has been reported in the paretic hand of individuals after stroke. Additionally, investigations have not been undertaken to study more challenging task constraints to induce the impairment of reach-to-grasp co-ordination. This study aimed to compare reach-to-grasp co-ordination while avoiding an obstacle in the paretic hand of individuals after stroke with matched non-disabled adults.*

Material and Method: *Twenty-four participants having mild severity of upper extremity impairment were recruited with an equal number of non-disabled adults. Kinematic reach-to-grasp movements with obstacle avoidance were analyzed. Reach-to-grasp co-ordination was quantified using cross-correlation analysis: maximum correlation coefficient represented the spatial aspect and the time lag represented the temporal aspects.*

Results: *Individuals after stroke showed a significant disturbance in the temporal aspect of reach-to-grasp co-ordination, but not the spatial aspect as compared with non-disabled adults.*

Conclusion: *Among participants, after stroke reach-to-grasp co-ordination was delayed in the temporal aspect of reach-to-grasp with obstacle avoidance but preserved in the spatial aspect. Specific methods to assess reach-to-grasp co-ordination and to treat the time delay to improve co-ordination should be considered in individuals after stroke.*

Keywords: *Motor control, Reach-to-grasp co-ordination, Dexterity*

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Activities of daily living are primarily upper extremity tasks, many of which involve a reach-to-grasp movement. Reach-to-grasp (RTG) is a complex motor skill requiring the integration of its two components: 1) transport- the planning and execution of reaching and 2) grasping movement. Both are termed a higher-order control system(1,2). These two components must be co-ordinated spatially, involving the pattern of movement, and timing, to preserve the optimal RTG performance and ensure that the object can be grasped successfully. Transport-grasp movement is disrupted in the paretic hand following stroke(3-7). Although deficits in transport-grasp movement are present, only a few studies have assessed this transport-grasp co-ordination disruption in individuals with stroke(4-7). In those studies, conflicting results in the co-ordination of the paretic hand were found. Factors accounting for these findings could be the different designs in task condition, varied movement speed and different ways of analyzing co-ordination parameters. Tretriluxana in 2008 proposed an interesting direct task constraint, a barrier task, and a sensitive measure, cross correlation analysis, to investigate transport-grasp co-ordination(8-10). Tretriluxana found an impairment of transport-grasp co-ordination in the non-paretic limb after stroke compared with age-matched non-disabled adults(8). This finding indicates that the barrier task and the cross correlation analysis are sensitive enough to detect the impairment of transport-grasp co-ordination in the non-paretic limb after stroke. Performing RTG movement under the barrier task and at a fast speed would challenge the motor planning of the RTG movement. Cross correlation analysis would magnify any transport-grasp co-ordination impairment. The aim of the

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study was to compare the kinematic reach-to-grasp movements including spatial aspect (pattern of movement) and temporal aspect (timing) of transport-grasp co-ordination in the paretic limb of individuals after stroke compared with matched non-disabled adults. We hypothesized that the co-ordination in paretic limb would be disrupted both in spatial and temporal aspects when performing RTG movement using a barrier task.

Material and Method

Study population

Right-handed individuals after stroke were recruited with an equal number of age-matched non-disabled adults. Individuals after stroke had a unilateral stroke no earlier than one month, were able to perform RTG task and had no musculoskeletal or other neurological problems affecting the task performance. The level of paresis was measured as mild by the Fugl Myer assessment (FMA). Participants were recruited from the Hospital and Physical Therapy Clinics in Bangkok and Nakhonpathom Provinces. The present study was approved by the Institutional Review Board, Mahidol University (COA. No. MU-IRB 2010/080.1603).

Experimental setup

The participants sat in front of a table with the object to be grasped located at 30 cm from the start switch immediately in front of the individual. The barrier, placed at the same side of paretic limb, was located at 15 cm to the front of the start switch and 2.5 cm away from the midline. The details of our protocols were described elsewhere[7-9]. RTG movement was performed under a foamed shield placed between starting switch and barrier, which occluded observing the arm and hand at the initial part of movement and allowed for observing the end of movement[8-10]. The visual occlusion of the arms and hands was applied to minimize the use of feedback. The instruction was "upon the sound, reach as fast as possible without a bumping the barrier, grasp the object with your thumb and index finger and lift it off". Individuals after stroke performed the task with their paretic limbs and non-disabled adults performed the same protocol using their matched limb. Twenty successful trials of RTG movement were collected and middle 15 trials were used in the analysis.

Data acquisition and analysis

Kinematic data were recorded using an electromagnetic motion system (Motion Monitor Innsport, Inc.). One sensor was attached on the styloid process of the wrist and two sensors were attached on the nail beds of the thumb and index fingers. Kinematic variables, shown in Fig. 1, included: 1) total movement time (TMT), 2) transport component: maximum transport velocity (MV), time of maximum transport velocity (TMV), 3) grasp component: maximum aperture (MA) and time of maximum aperture (TMA). The variable of transport-grasp co-ordination was assessed by cross correlation analysis between transport velocity and grasp aperture trajectories. Spatial co-ordination was derived from the correlation coefficient at the most similar pattern between the transport velocity and grasp aperture trajectories, called maximum correlation coefficient (r_{max}). Temporal co-ordination was quantified by the time used to shift the transport velocity trajectory relative to the grasp aperture trajectory until the r_{max} was detected. This is termed maximum associated time lag (T_{max}), Fig. 2.

Statistical analysis

Multivariate analysis of variance (MANOVA) was used to compare the kinematic value between the individuals after stroke and matched non-disabled adults. Significant level was set at $p<0.05$.

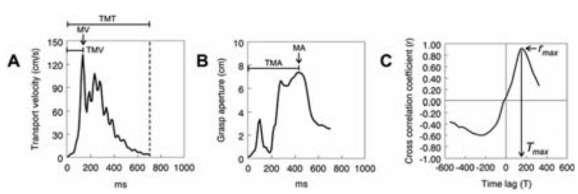

Fig. 1 Kinematic parameter of transport velocity (A), grasp aperture (B) and cross correlation plot (C) for a representative trial of RTG movement of a non-disabled participant.

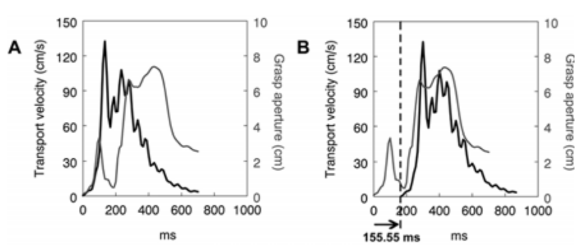

Fig. 2 Transport velocity (black) and grasp aperture (gray) trajectories over time for one trial of RTG movement. (A) Original trajectory. T = 0, r = 0.05. (B) After cross-correlation analysis technique. The transport velocity trajectory was shifted (arrow line) to achieve the most similar pattern with grasp aperture trajectory. T_{max} = 155.55 ms, r_{max} = 0.91.

Results

Participant characteristics

Twenty-four individuals after stroke, 12 right (4 women) and 12 left hemiparesis (6 women), participated in the study. Mean time since stroke was 28.7±31.7 months. All individuals after stroke had mild severity with upper extremity FMA scores of 58.7±4.7. The non-disabled adults, the control group, were equivalent in mean age (58.2±8.6 years) when compared with the stroke group.

Transport and grasp components

Table 1 summarizes mean data of each parameter in transport and grasps components performed by control and stroke groups. As expected, the transport measures of TMT, TMV and TMA of the stroke group were significantly longer than that of the control group. MV of stroke group was significantly lower than that of the control group. In contrast, the spatial measure, MA, was similar between both groups.

Transport-grasp co-ordination

No significant differences were found in spatial co-ordination, r_{max} between the stroke (0.75±0.04) and control groups (0.78±0.05). In contrast, temporal co-ordination, T_{max} of transport-grasp movement in the stroke group (272.5±132.9 ms) was significantly longer compared with the control group (141.0±40.7 ms, p = 0.001).

Discussion

Performing a complex RTG action quickly with a partial visual block and a barrier condition challenged transport-grasp co-ordination. The authors found a deficit in overall performance of RTG action as indicated by prolonged movement time. Despite mild severity of upper extremity impairment, the temporal transport-grasp co-ordination, representing a visuomotor integration of higher-order control systems, was perturbed[1]. This experimental design and measurement, i.e. barrier avoidance under fast speed and cross correlation analysis, was sensitive enough to detect co-ordination impairment even in mild severity individuals-after stroke. Our transport-grasp co-ordination result conflicted with the previous study regarding the non-paretic limb of individuals with stroke. Tretriluxana reported that individuals with stroke, having mild to moderate arm impairment (FMA scores 43-54), had deficit in both spatial and temporal aspects of RTG. In contrast, individuals after stroke, having mild severity of the paretic limb in our study showed the co-ordination deficit only in the temporal aspect. The different findings may suggest that individuals with less arm impairment have more intact spatial aspects of movement co-ordination. Those having more severity of arm impairment tended to be disturbed in both spatial and temporal aspects of transport-grasp co-ordination.

One possible explanation is spatiotemporal trade-off[11]. Spatial components of movement may be retained while temporal control is delayed. The greater attention required to track the spatial aspect of movement, the slower the movement[11]. The deficit in temporal co-ordination may be based on the scheduling process of RTG timing concept proposed by Tretriluxana[8]. The minimal velocity of wrist transport triggers the initiation of the second phase of grasp pre-shaping[8]. The delayed activation in muscles controlling the reach or grasp of components[12,13] may have altered the timing of the second phase of grasp pre-shaping, leading to a deficit in the temporal aspect of the RTG action.

Conclusion

Reach-to-grasp performance deficit was found in the temporal aspect transport-grasp co-ordination in the paretic limb of individuals with mild severity after stroke. The RTG task with the barrier condition is an

Table 1. Reach-to-grasp movement; mean (SD)

Reach-to-grasp parameters	Control (n = 24)	Stroke (n = 24)	*p*-value
Total movement time (ms)	658.48 (105.50)	1,132.79 (359.65)	<0.001
Transport component			
Maximum transport velocity (cm/s)	151.23 (40.21)	88.59 (26.09)	<0.001
Time of maximum transport velocity (ms)	163.14 (47.05)	283.60 (143.69)	<0.001
Grasp component			
Maximum aperture (cm)	6.66 (0.93)	6.33 (1.62)	>0.05
Time of maximum aperture (ms)	379.39 (53.82)	704.81 (261.38)	<0.05

effective method to assess transport-grasp co-ordination. Our findings suggested that the intervention for individual after stroke might focus on improving the speed of movement to enhance reach-to grasp co-ordination.

What is already known on this topic?

Conflicting results in the reach-to-grasp (transport-grasp) co-ordination deficit of the paretic limb were found when individuals with stroke performed reach-to-grasp movement with an indirect task constraint, a non-barrier task. Using a more challenging task constraint, a barrier task and a sensitive measure, cross correlation analysis is able to detect the co-ordination deficit in the non-paretic limb.

What this study adds?

This is the first study to demonstrate impairment of the temporal, but not the spatial aspect of reach-to-grasp co-ordination in mild severity individuals after stroke.

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Potential conflicts of interest

None.

References

1. Jakobson LS, Goodale MA. Factors affecting higher-order movement planning: a kinematic analysis of human prehension. Exp Brain Res 1991; 86: 199-208.
2. Jeannerod M. Intersegmental coordination during reaching at natural visual objects. In: Long J, Baddeley A, editors. Attention and performance. New Jersey: Lawrence Erlbaum; 1981: 153-68.
3. Lang CE, Wagner JM, Bastian AJ, Hu Q, Edwards DF, Sahrmann SA, et al. Deficits in grasp versus reach during acute hemiparesis. Exp Brain Res 2005; 166: 126-36.
4. Nowak DA, Grefkes C, Dafotakis M, Kust J, Karbe H, Fink GR. Dexterity is impaired at both hands following unilateral subcortical middle cerebral artery stroke. Eur J Neurosci 2007; 25: 3173-84.
5. Michaelsen SM, Jacobs S, Roby-Brami A, Levin MF. Compensation for distal impairments of grasping in adults with hemiparesis. Exp Brain Res 2004; 157: 162-73.
6. Michaelsen SM, Magdalon EC, Levin MF. Grip aperture scaling to object size in chronic stroke. Motor Control 2009; 13: 197-217.
7. van Vliet PM, Sheridan MR. Coordination between reaching and grasping in patients with hemiparesis and healthy subjects. Arch Phys Med Rehabil 2007; 88: 1325-31.
8. Tretriluxana J. Hemispheric specialization of reach-to-grasp actions [dissertation]. Los Angeles, CA: University of Southern California; 2008.
9. Tretriluxana J, Gordon J, Winstein CJ. Manual asymmetries in grasp pre-shaping and transport-grasp coordination. Exp Brain Res 2008; 188: 305-15.
10. Tretriluxana J, Gordon J, Fisher BE, Winstein CJ. Hemisphere specific impairments in reach-to-grasp control after stroke: effects of object size. Neurorehabil Neural Repair 2009; 23: 679-91.
11. Almeida QJ. Timing control in Parkinson's disease. In: Dushanova J, editor. Mechanisms in Parkinson's disease-models and treatments. Rijeka, Croatia: InTech; 2012: 39-56.
12. Chae J, Yang G, Park BK, Labatia I. Delay in initiation and termination of muscle contraction, motor impairment, and physical disability in upper limb hemiparesis. Muscle Nerve 2002; 25: 568-75.
13. Seo NJ, Rymer WZ, Kamper DG. Delays in grip initiation and termination in persons with stroke: effects of arm support and active muscle stretch exercise. J Neurophysiol 2009; 101: 3108-15.

การประสานสัมพันธ์ของการเอื้อมและการหยิบจับด้วยแขนข้างอ่อนแรงของผู้ป่วยโรคหลอดเลือดสมอง: ความเข้าใจลึกซึ้งจากการใช้สิ่งกีดขวาง

ณัฐกาญจน์ รุณรงค์, จารุกูล ตรีไตรลักษณะ, วิมลวรรณ เหียงแก้ว, รุ่งทิวา วัจฉละฐิติ

วัตถุประสงค์: *การเอื้อมและการหยิบของนั้นต้องประสานสัมพันธ์กันเพื่อคงไว้ซึ่งประสิทธิภาพในการเอื้อมมือหยิบของ อย่างไรก็ตามมีความขัดแย้งกันเกี่ยวกับความบกพร่องของการประสานสัมพันธ์ขณะเอื้อมมือหยิบของในแขนข้างอ่อนแรงของผู้ป่วยโรคหลอดเลือดสมอง และยังไม่มีการทดลองที่ท้าทายเพื่อศึกษาความบกพร่องของการประสานสัมพันธ์นี้ งานศึกษาจึงมีวัตถุประสงค์เพื่อศึกษาการประสานสัมพันธ์ขณะเอื้อมมือหยิบของขณะมีสิ่งกีดขวางด้วยแขนข้างอ่อนแรงในผู้ป่วยโรคหลอดเลือดสมอง*

วัสดุและวิธีการ: *ผู้ป่วยโรคหลอดเลือดสมองที่มีความบกพร่องของแขนน้อยและคนปกติกลุ่มละ 24 รายได้รับการทดสอบทางไคเนมาติกส์ของแขนและมือขณะเอื้อมมือหยิบของที่มีสิ่งกีดขวางตั้งอยู่ ประเมินการประสานสัมพันธ์ขณะเอื้อมมือหยิบของโดยวิเคราะห์สหสัมพันธ์แบบไขว้ประกอบด้วยการประสานสัมพันธ์ด้านรูปแบบและเวลา*

ผลการศึกษา: *ผู้ป่วยโรคหลอดเลือดสมองมีความบกพร่องอย่างมีนัยสำคัญทางสถิติในการประสานสัมพันธ์ด้านเวลา เมื่อเทียบกับคนปกติ แต่ไม่บกพร่องในการประสานสัมพันธ์ด้านรูปแบบ*

สรุป: *มีความบกพร่องด้านเวลาการประสานสัมพันธ์ของการเอื้อมมือหยิบของขณะมีสิ่งกีดขวาง ในผู้ป่วยโรคหลอดเลือดสมองจึงควรมีการตรวจและรักษาที่เจาะจงเพื่อเพิ่มการประสานสัมพันธ์ขณะเอื้อมมือหยิบของ*