Human Movement Science 57 (2018) 50–58

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

# One year after ischemic stroke: Changes in leg movement path stability in a speed–accuracy task but no major effects on the hands

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ARTICLE INFO

*Keywords:*
Postsroke
Motor performance recovery
Motor strategy
Movement speed and accuracy

ABSTRACT

First year after the stroke is essential for motor recovery. The main motor control strategy (i.e., faster movement production at the expense of lower movement accuracy and stability, or greater movement accuracy and stability at the expense of slower movement) selected by poststroke patients during a unilateral speed–accuracy task (SAT) remains unclear. We aimed to investigate the poststroke (12 months after stroke) effects on the trade-off between movement speed and accuracy, and intraindividual variability during a motor performance task. Healthy right-handed men (n = 20; age ~ 66 years) and right-handed men after ischemic stroke during their post rehabilitation period (n = 20; age ~ 69 years) were asked to perform a simple reaction task, a maximal velocity performance task and a SAT with the right and left hand, and with the right and left leg. In the hand movement trial, reaction time and movement velocity ($V_{max}$) in the SAT were slower and time to $V_{max}$ in the SAT was longer in the poststroke group ($P < .01$). In the leg movement trial, poststroke participants reached a greater $V_{max}$ in the SAT than the healthy participants ($P < .01$). The greatest poststroke effect on intraindividual variability in movements was found for movement path in the SAT, which was significantly greater in the legs than in the hands. Poststroke patients in the first year after stroke mainly selected an impulsive strategy for speed over hand and leg motor control, but at the expense of lower movement accuracy and greater variability in movement.

## 1. Introduction

It is well established that stroke decreases the force and velocity of movements and increases task errors and movement variability (Cirstea & Levin, 2000; Kang & Cauraugh, 2015; Sethi et al., 2013; Tippett, Alexander, Rizkalla, Sergio, & Black, 2013). For example, poststroke individuals walk with greater instability and gait variability than neurologically intact controls (Kao, Dingwell, Higginson, & Binder-Macleod, 2014). The various motor impairments found after stroke are caused by disruption of descending neural commands and changes in spinal neuron excitability (Elbasiouny, Moroz, Bakr, & Mushahwar, 2010; Mirbagheri, Tsao, & Rymer, 2009). These mechanisms may include deficits caused by altered cortical commands and/or changes in peripheral neuromuscular properties (Mirbagheri et al., 2009). Evidence indicates that damage to a single hemisphere produces sensorimotor deficits in both the contralesional and ipsilesional arms (Chang et al., 2010; Hammerbeck et al., 2017; Kwon, Kim, & Jang, 2007; Levin, Liebermann, Parmet, & Berman, 2016; Noskin et al., 2008; Schaefer, Haaland, & Sainburg, 2007). The walking function has greater potential for recovery than the hand function because the motor function of the legs is less dependent on the lateral corticospinal tract than the hand function (Jang, 2010). Repetitive task training leads to modest improvements according to a range of lower limb outcome measures,

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https://doi.org/10.1016/j.humov.2017.11.005
Received 25 May 2017; Received in revised form 6 November 2017; Accepted 7 November 2017

but not upper limb outcome measures (French et al., 2010).

It has been suggested that goal-directed behavior is characterized by a trade-off between the speed of responding and the accuracy of performance (Heitz & Schall, 2012). Thus, the ability to trade-off speed and accuracy against each other is a hallmark of decision-making in various species and tasks (Gallivan, Logan, Wolpert, & Flanagan, 2016; Heitz & Schall, 2012; Standage, Blohm, & Dorris, 2014). Another factor involved in decision-making during a speed–accuracy task (SAT) is movement variability, which is undesirable during such tasks (Wolpert & Flanagan, 2016). However, despite these observations, no previous study has examined speed–accuracy tasks during decision-making in poststroke patients by comparing the functional characteristics of motor performance in the damaged and intact side extremities (i.e., including left or right side hands vs. legs; left vs. right hands or legs) in a speed–accuracy sensorimotor task. For example, Conti, Sterr, Brucki, and Conforto (2015) conclude that stroke decreases the executive function and reduces the ability to initiate, control, and monitor goal-directed movements. Thus, the main motor control strategy (i.e., faster movement production at the expense of lower movement accuracy and stability, or greater movement accuracy and stability at the expense of slower movement) selected by poststroke patients during a SAT remains unclear.

Therefore, the main aim of the present study was to investigate the poststroke (12 months after stroke) effects on movement speed and accuracy, as well as intraindividual variability during a speed–accuracy sensorimotor task and whether it depends on the right vs. left and upper vs. lower limbs. At 12 months after ischemic stroke, we tested whether hand and leg movements of stroke survivors with a damaged right-side hemisphere were slower and less accurate compared with those by the intact side, and whether these differences (indicate change in motor control strategy) were more evident in the hands than the legs.

## 2. Methods

### 2.1. Ethics statement

This study was conducted in accordance with the Declaration of ***Helsinki (1964). Permission (No. BE-2-72) for the study was obtained from Kaunas Regional Ethics Committee for Biomedical Research.

### 2.2. Participants

The baseline data of participants' characteristics are shown in Table 1. In addition, the inclusion criteria for the stroke patients and healthy controls were: 1) no hearing or vision disorders that could hinder performance of the task; 2) no diseases of the central and peripheral nervous system (e.g., Parkinson's disease, multiple sclerosis, mental disorders, brain or medullar tumors, or epilepsy); 3) no orthopedic condition that could affect the performance; 4) no pain in the arm or leg; and 5) no medications that could affect the muscle performance.

### 2.3. Movement tasks

The participants were asked to perform three tasks in the following order: 1) a simple reaction task (SRT) with one hand or leg (20 repetitions with the right or left hand, and with the right or left leg); 2) a maximal velocity performance task (MVT) with one hand or leg (10 repetitions with the right or left hand, and with the right or left leg); and 3) a unilateral SAT with the right or left hand, as well as the right or left leg, where the participant had to react as quickly as possible and move to the target as fast and as accurate as possible (20 repetitions were performed with each hand or leg). The interval between repetitions of the tasks was 1–3 s and the interval between tasks with different hands or legs was 1 min. The hands or legs were chosen randomly for each task performance.

Familiarization day. At 5–6 days before the experiment, the participants were introduced to all of the tasks, where they performed

**Table 1**
Baseline characteristics of the subjects.

| | Poststroke | Healthy |
|---|---|---|
| Age, years | 68.6 ± 6.4 | 68.5 ± 6.1 |
| Males, % (n) | 100 (20) | 100 (20) |
| Weight, kg | 75.8 ± 6.4 | 74.6 ± 7.6 |
| Height, cm | 1.68 ± 0.04 | 1.7 ± 0.05 |
| Body mass index | 26.7 ± 2.2 | 25.7 ± 2.9 |
| Time from stroke onset, months | 12–13 | – |
| Chronic stroke period (> 6 months from onset), % (n) | 100 (20) | – |
| Lesion lateralization, % (n) | Right hemisphere 100 (20) | – |
| Lesion localization, % (n) | Middle cerebral artery basin 100 (20) | – |
| Initial Mini-Mental State Examination score | 27.4 ± 1.14 | 29.8 ± 0.52 |
| Initial spasticity Ashworth score | 0 | – |
| Initial upper and lower extremity muscle strength (OGS) score | 4.43 ± 0.37 | 4.57 ± 0.23 |
| Initial Berg balance score | 51.1 ± 4.05 | 55.6 ± 0.69 |
| Initial Barthel index | 94.5 ± 4.26 | 99.9 ± 0.1 |

Values are means ± standard deviation (SD).