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Difference of motor overflow depending on the impaired or unimpaired hand in stroke patients

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ABSTRACT

The aim of this study was to investigate the patterns of contralateral motor overflow (i.e. mirror movement) between the homologous body parts on the right and left side, in stroke patients during single-finger and multi-finger maximum force production tasks. Forty subjects, including stroke (n = 20) and normal subjects (n = 20), participated in this study. The stroke subjects maximally pressed force sensors with their fingers in a flexed position using a single (index, middle, ring, or little) or all fingers (all 4 fingers) using the impaired (IH) or unimpaired (UIH) hand, while the non-patient subjects used their right hands for the same tasks. The maximal voluntary forces in the ipsilateral and unintended pressing forces of each contralateral finger were recorded during the tasks. The magnitude of motor overflow to the contralateral side was calculated using the index of contralateral independence (CI). During the single finger tasks, the finger CI was significantly decreased in the UIH (91%) compared with that in the IH (99%) or normal hands (99%). Likewise, the multiple finger tasks showed that the CI was significantly lower in the UIH (84%) compared with that in the IH (96%) or normal hands (99%). However, the maximal forces were significantly lower in the IH relative to those in the UIH

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and normal hands. These data demonstrate that stroke patients have greater motor overflow from the UIH to the IH.

1. Introduction

Manual motor tasks impose rather strict requirements of forces and some level of independence between fingers and between hands (Park, Kim, & Shim, 2010; Shim, Hsu, Karol, & Hurley, 2008). After a stroke, the corticospinal projections can be severely damaged (Colebatch & Gandevia, 1989; Shelton & Reding, 2001) and it is often accompanied by dysfunction of hands because of the cortical nature of the hand control and a large hand representation in the cortexes (Schieber, 2001; Schieber & Poliakov, 1998). It has been reported that the function and dexterity of the hand and fingers are critical in terms of the quality of life of stroke patients (Nakayama, Jorgensen, Raaschou, & Olsen, 1994).

The motor control dysfunction of stroke patients is associated with not only the motor output of specific motor effectors (i.e., muscles, body segments, etc.), but also the interactions between them. In particular, a decreased independence in individual finger control can easily reduce hand dexterity (Schieber, Lang, Reilly, McNulty, & Sirigu, 2009). Both excitation of intended motor neurons and inhibition of unintended motor neurons are required for independent finger control, which seems to be difficult in stroke patients (Schieber et al., 2009). For instance, previous studies have shown that stroke is associated with decreased intended finger forces and increased unintended finger forces within the damaged hemisphere during single and multiple finger force production (Kim, Kim, & Yoon, 2014; Li, Latash, Yue, Siemionow, & Sahgal, 2003). This phenomenon indicates that independent finger control is hampered in stroke patients due to the motor selectivity defect.

The motor output within one side of a hemisphere can overflow into the motor cortex of the contralateral hemisphere. This phenomenon is called motor overflow when the mirror movement occurs in the contralateral homologous body part (Connolly & Stratton, 1968). Although the phenomenon of motor overflow can normally be observed in children, the maturation of the central nervous system progressively inhibits the excitation of contralateral motor neurons so that it disappears at adolescence (Lazarus & Todor, 1987). Pathologically, motor overflow can be observed in hemiplegic stroke patients. Clinically, motor overflow is characterized by associated reactions or dystonia, in which unintended body segments moderately move during movements of intentional body parts. A previous study suggested bilateral motor output by the unilateral motor cortex in stroke patients, providing neurologic evidence in support of motor overflow (Cramer, Finklestein, Schaechter, Bush, & Rosen, 1999). Motor overflow more frequently appears in the upper extremities and distal body segments (Ada & O'Dwyer, 2001; Honaga et al., 2007). Thus, we hypothesized that the manifestation of motor overflow in stroke patients would affect the motor selectivity of the hand and fingers.

This study aimed to identify finger motor overflow in stroke patients using computational analysis of individual finger forces. We hypothesized that stroke patients have decreased independence in force production between hemispheres. To demonstrate the changes in the independence of the inter-hemispheres we compared the unintended finger forces of the contralateral side during a maximal voluntary force (MVF) production task using the impaired hand (IH) and unimpaired hand (UIH) in stroke subjects and the dominant hand in normal subjects.

2. Methods

2.1. Subjects

Twenty stroke patients and twenty age-matched normal subjects participated in this study. The main inclusion criterion for the stroke group was patients with hemiparesis caused by ischemic or hemorrhagic stroke. Exclusion criteria for both groups included finger amputation, paresthesia, vision or hearing impairments, and cognitive impairments.