Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2016;97:798-806

ORIGINAL RESEARCH

Task-Dependent Bimanual Coordination After Stroke: Relationship With Sensorimotor Impairments

Shailesh S. Kantak, PT, PhD,[a,b] Nazaneen Zahedi, BS,[a] Robert L. McGrath, BME[a]

From the [a]Neuroplasticity and Motor Behavior Laboratory, Moss Rehabilitation Research Institute, Elkins Park, PA; and [b]Department of Physical Therapy, Arcadia University, Glenside, PA.

Abstract

Objectives: To determine (1) bimanual coordination deficits in patients with stroke using 3-dimensional kinematic analyses as they perform naturalistic tasks requiring collaborative interaction of the 2 arms; and (2) whether bimanual coordination deficits are related to clinical measures of sensorimotor impairments and unimanual performance of the paretic arm.

Design: Case-control study.

Setting: Rehabilitation hospital research institute.

Participants: Participants (N=24) were patients with unilateral chronic stroke (n=14) and age-matched controls (n=10).

Interventions: Not applicable.

Main Outcome Measures: Temporal coordination between the 2 hands as participants performed (1) a symmetric task: reach to pick up a box using both hands; and (2) an asymmetric task: open a drawer with 1 hand to press a button inside with the other hand.

Results: During the symmetric task, patients and controls showed preserved temporal coupling while transporting the hands to the box. However, on reaching the box, patients demonstrated an impaired ability to cooperatively interact their 2 arms for an efficient pickup. This led to significantly longer pickup times compared with controls. Pickup time positively correlated with proprioceptive deficits of the paretic arm. During the asymmetric task, patients had a longer time delay between drawer opening and button pressing movements than controls. The deficits in asymmetric coordination did not significantly correlate with sensorimotor impairments or unimanual paretic arm performance.

Conclusions: Bimanual coordination was impaired in patients poststroke during symmetric and asymmetric bimanual tasks that required cooperative interaction between the 2 arms. While the proprioceptive system contributes to symmetric cooperative coordination, commonly tested measures of paretic arm impairment or performance, or both, do not strongly predict deficits in bimanual coordination.

Archives of Physical Medicine and Rehabilitation 2016;97:798-806

Bimanual activities are ubiquitous in daily life and require the 2 arms to simultaneously interact with each other to accomplish functional tasks.[1] After a unilateral stroke, unimanual deficits are evident in the contralateral (paretic) arm and have been the focus of extensive research.[2-5] In addition, deficits in the ipsilateral (nonparetic) arm are also present.[6] Given these changes in both arms, the skill and coordination with which individuals perform bimanual tasks that require the 2 arms to work collaboratively may also be impaired.

Research investigating bimanual coordination after stroke has largely focused on how movements of 1 arm influence those of the other in highly controlled laboratory-based tasks.[7-10] While these studies have proven useful to understand the inherent linkages in bimanual coordination, such movements are far from being illustrative of daily bimanual actions. In daily life, we perform a myriad of movements where the 2 hands cooperatively interact in precise spatiotemporal coordination to accomplish a common functional goal. There is a clear gap in the literature about how patients with stroke coordinate their arms to accomplish bimanual tasks that require such cooperative interaction between the 2 arms. In addition, it is not known whether sensorimotor impairments in the paretic arm relate to bimanual coordination deficits.

In this study, our objective was to investigate the coordination between the 2 arms while individuals with stroke and age-matched controls perform 2 naturalistic tasks that require cooperative interaction between the 2 arms. A naturalistic action is a learned,

Supported by the Moss Rehabilitation Research Institute.
Disclosures: none.

0003-9993/16/$36 - see front matter © 2016 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2016.01.020

object-driven behavior that is used when performing daily activities.[11-13] One task engaged the 2 arms symmetrically to reach and pick up a box. The second, an asymmetric task, required participants to press a button with 1 hand, which was made accessible by opening the drawer with the other hand. While these tasks have been previously used to study bimanual coordination in healthy controls,[14] we used kinematic analyses to investigate the differences in bimanual coordination between patients with stroke and age-matched controls. Our second objective was to determine whether bimanual coordination in patients with stroke is related to clinical measures of sensorimotor impairments and unimanual performance of the paretic arm.

We hypothesized that participants poststroke would demonstrate impaired bimanual coordination during performance of cooperative symmetric and asymmetric tasks. We also hypothesized that bimanual coordination deficits during naturalistic bimanual task performance would be related to clinical measures of sensorimotor impairments and unimanual performance deficits in the paretic arm.

Methods

Participants

Fourteen patients with chronic stroke (mean age ± SD, 53±15.4y) and 10 controls (mean age ± SD, 59.75±23.06y) participated in a case-control study. All participants gave written informed consent approved by the institutional review board. Participants were excluded if they (1) had complete plegia of the affected arm and were not able to reach 60% of their arm length during supported reaching; (2) could not follow instructions; or (3) had hemispatial neglect (tested by line bisection test). Table 1 summarizes the clinical characteristics of the participants with stroke.

In stroke participants, motor impairment was measured using the upper extremity Fugl-Meyer (UEFM)[15] and isometric strength testing.[16] Strength of the bilateral anterior deltoids and triceps was measured using a hand-held dynamometer during an isometric contraction; a 3-trial average was calculated for the paretic and nonparetic arm. The strength of the hemiparetic arm was quantified as a percentage of the nonparetic arm $\left(\frac{paretic}{nonparetic} * 100\%\right)$. A unified measure of strength was determined by taking an average of the strength scores of the paretic deltoid and triceps. Sensory examination included proprioception and fine touch testing. Proprioception deficit was determined using an elbow position matching task[17,18] while participants were blindfolded. A greater difference between the passively positioned paretic arm and the actively matched nonparetic arm position indicated greater proprioceptive deficits. An average was calculated for 10 trials. Fine touch sensation was tested over the hand using Semmes-Weinstein monofilaments. The pressure of the smallest monofilament sensed was recorded as a measure of touch sensation.

List of abbreviations:

GS	**goal synchronization**
MT	**movement time**
OS	**onset synchronization**
PTP	**pull to press**
RTP	**reach to pickup**
TC	**transport coordination**
UEFM	**upper extremity Fugl-Meyer**

Experimental setup

Participants were seated in a straight-back chair at a table with their trunk constrained to the chair. Before testing, maximal active forward reach distance with the marker on the dorsum of the hand was recorded to standardize the object placement across participants with different arm lengths and disabilities. We investigated the kinematics and coordination between the 2 hands while the participants performed 2 naturalistic tasks. Studying naturalistic tasks using kinematic analyses allows better quantification of everyday action impairments, thus establishing strong external validity for studying the underlying impairments.[11,13]

The symmetric task involved a forward reach to pick up a box and lift it to shoulder height. A 0.6-lb box, 33×37×11.5cm, was placed on the table at 80% of the participant's maximal forward reach distance (paretic arm for individuals with stroke). Three conditions were tested: (1) bimanual: participants were instructed to simultaneously reach with both hands and pick up the box; (2) right unimanual and (3) left unimanual: participants were asked to place either their right or left hand on the sides of the box. The unimanual condition included only the reach component without any requirement to pick up the box.

The asymmetric task required individuals to open a drawer with 1 hand and insert their contralateral hand in the drawer to press a pushbutton (7.57.5cm). The drawer (35×28×11.5cm) with a loop handle was placed in front of the participants such that the pushbutton in the drawer was at 80% of their maximal forward reach of their nondominant/paretic arm. Three conditions were tested: (1) bimanual: participants were instructed to press a pushbutton switch with their nondominant (controls)/paretic (stroke) hand by opening a drawer with their dominant/nonparetic arm; (2) unimanual open condition: participants were asked to open the drawer with their dominant/nonparetic arm; and (3) unimanual press condition: with the drawer open, participants were asked to reach forward and press the pushbutton with their nondominant/paretic hand. Patients opened the drawer with their nonparetic arm because grasping the drawer handle required dexterous control that their paretic hand often lacked. No specific instructions were given about the extent of drawer opening.

After 5 practice trials, 20 test trials were collected for each task and condition. Participants were instructed to complete the task as fast and as smoothly as possible when ready following the "go" signal. The tasks were not presented as reaction time tasks because we wanted them to have enough time to plan the movements as efficiently as possible.

Data acquisition

Kinematic data were acquired using an electromagnetic motion tracking system (3D-guidance trackSTAR[a]). A single 6-degrees-of-freedom sensor (19×8×8mm)[a] was secured to the dorsum of each hand. Sensors were also placed on the box, drawer, and the pushbutton to indicate their position throughout each trial. Position data, captured at 250Hz, were filtered using a zero-phase lag, low-pass, fourth-order Butterworth filter (10-Hz cutoff frequency). Hand paths and displacements for each arm were recorded and differentiated to derive tangential velocities. Kinematic landmarks