Introduction: The first few days after acute stroke are characterized by multiple and complex biological processes resulting in dramatic changes in patient presentation. Given this dynamic early change, there is a lack of clarity on when to gather baseline motor assessments for recovery trials. Here, we aimed to characterize early change in global and upper limb motor impairment as measured by the National Institute of Health Stroke Scale (NIHSS) to determine when stroke related deficits stabilize and recovery begins. We also aimed to test the hypothesis that upper limb motor impairment at distinct timepoints during acute hospitalization would differentially explain long-term motor outcomes.

Methods: Ninety-eight individuals with upper limb motor impairment after acute stroke were prospectively enrolled in a motor rehabilitation study (NCT03485040). NIHSS (total and motor sub-score) were collected at four timepoints during the acute hospitalization: admission (<6 hours), 24 hours, 72 hours (from symptom onset), and discharge. A mixed-effects regression model was used to assess mean change between timepoints. Multiple linear regression was performed to determine potential factors (acute stroke therapies, medical comorbidities, premorbid function, baseline NIHSS score) that explained change in total NIHSS between timepoints. Long-term upper limb motor impairment was measured by the Fugl-Meyer assessment 90 days post-stroke, and linear regression analyses were performed to determine which timepoints explained the most variance in outcome.

Results: The 98 participants (mean age 64.2 ± 13.1, 49% female) had an average acute stroke hospitalization length of 7.6 ± 5.0 days. On initial presentation, the cohort had an average total NIHSS score of 11 ± 7.0 and motor subscore of 2 ± 1.5. Total $NIHSS_{admission\text{-}24hr}$ had a significantly larger mean magnitude of change (5.54 ± 4.89 points) compared to the later change windows: Total $NIHSS_{24\text{-}72hr}$ (2.33 ± 2.15) and Total $NIHSS_{72hr\text{-}discharge}$ (3.06 ± 2.34), indicating that the greatest change occurred in the first 24 hours after stroke. Endovascular therapy and diabetes were predictive of total change from admission to 24 hours ($p < 0.001$). Premorbid cardiac disease predicted change from 72 hours to discharge ($p < 0.001$). Multiple linear regression analyses demonstrated that 24, 72, and discharge NIHSS motor scores were significant predictors of 3-month Fugl-Meyer ($p=0.001$ for all three), while admission motor score was not.

Discussion: The most change (improvement and deterioration) happened from admission to 24-hours post-stroke. Distinct factors explained change in different time windows during the acute stroke hospitalization. Motor scores gathered at or after 24 hours predicted 90-day motor outcome, suggesting long-term motor recovery processes can be captured within this early time frame. Taken together, these results highlight distinct biological windows after acute stroke and provide insight into timing for baseline motor assessment.

Categories
Stroke

Impacts of exoskeleton on movement characteristics during multi-directional reaching tasks in healthy adults

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Introduction: Human reaching relies on intricate motor programs (synergies) that can be disrupted by neurological disorders or aging. While assistive exoskeletons have the potential for rehabilitation, their impact on reaching, due to added weight, mechanical restriction or applied force, remains unclear. In this study, we aimed to investigate how these interferences alter reaching movements.

Methods: Nine healthy participants at the age of 20.6 ± 1.6 years were included in this study. None of them had experience working with an exoskeleton before participating in the study. A commercial exoskeleton (Myomo Pro) controlled by muscle activations was used in this study. Each participant performed reach-and-grasp tasks at three conditions using the right arm: natural reaching without wearing the exoskeleton (NoExo), reaching while wearing the exoskeleton with power off (ExoOff), or power on (ExoOn). During the tasks, participants were asked to reach and grasp the object (an aluminum can) placed in one of the three locations (10 times at each location ordered randomly), including in the front of the participant (forward reach), and 45 degrees to the left (medial reach) and to the right (lateral reach). To characterize the reaching movements, we derived the variables in reaching and returning phases, including the distance between travelled trajectory and the straight line connecting the starting and target locations (DIS), transport time (TT), and travelled trajectory (TRJ), constituting six dependent variables. To examine the differences among conditions, we conducted the two-way repeated measures analysis of variance (ANOVA) with the level of significance set at $p<0.05$ and Bonferroni tests for multiple comparisons when appropriate.

Results: During the medial reach, ExoOn had a significantly larger DIS in both reaching and returning phases when

compared to NoExo (p=0.037 and p=0.044). The TT in ExoOff and ExoOn were significantly longer compared to TT in NoExo during the medial reach (p=0.008 and p=0.014) and the lateral reach (p=0.001 and p=0.03). During the reaching phase of forward reach, NoExo had a significantly shorter TT than ExoOff and ExoOn (p=0.005 and p=0.012) and ExoOff had a significantly shorter TT than ExoOn (p=0.005). When compared to NoEXO, ExoOn took significantly longer time to return from the medial, forward, and lateral reaches (p=0.006, 0.002 and 0.002). It also took longer time for ExoOn to return from the forward reach when compared to ExoOff.

Discussion: The exoskeleton assistance (ExoOn) might encumber the motion while the added weight or mechanical restriction of the exoskeleton (ExoOff) might have less effect on reaching. The larger distance deviated from the straight line seems more evident in the medial reach when the exoskeleton was powered.

Conclusion: Human reaching performance might vary depending on the directions. The design or adoption of the exoskeleton for movement assistance should consider task requirements for better outcome.

Categories
Other

Proximal Upper Extremity Motor Control Analysis in Stroke Patients: A Comparative Study of Principal Component Analysis-Mahalanobis Distance (PCA-MD) and Dynamic Time Warping (DTW)

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Background: Proximal motor control deficits are a core feature of upper extremity (UE) hemiparesis following stroke. Principal Component Analysis and Mahalanobis distance (PCA-MD) have been previously used to quantify these deficits by measuring deviation from healthy motion patterns. However, this method does not account for the temporal aspect of motor control, as they assess movements irrespective of time. This study introduces Dynamic Time Warping (DTW), an approach accounting for temporal component, and compares it with PCA-MD in stroke patients. We focus on the methodological significance of temporal elements in motor control evaluation and correlating the outputs of each method with conventional motor outcome assessments.

Methods: Twenty-two participants with UE motor impairment after acute stroke (4.6 $\pm$ 1.9 days poststroke, Fugl-Meyer range [7-65]) completed 80 trials of a planar reaching in a center-out task (8 directions) with their more affected UE on the Bionik InMotion2® Arm Therapy System, a clinical rehabilitation robotic system. A control population of 22 able-bodied adults completed the same planar reaching task. We computed both the PCA-MD and DTW scores of stroke planar reaching trials in relation to reaching trials of the able-bodied population. We investigated the relationship between both methods and UE outcome measures (Fugl-Meyer Assessment Upper Extremity [FMA-UE], Box and Block Test, and Nine Hole Peg Test). Spearman correlations were used to evaluate the relations between the PCA-MD and DTW methods, as well as between the methods and UE outcome measures.

Results: DTW demonstrated high correlation with PCA-MD score (Spearman correlation: r=0.91, $p<0.001$), despite differences in temporal data handling. Both PCA-MD and DTW scores showed strong correlations with functional outcomes (Box and Block Test, Nine-Hole Peg Test). Correlations between PCA-MD and DTW scores with FMA-UE were statistically significant, but weaker (Spearman correlation: r=0.46, p=0.031, and r=0.47, p=0.028, respectively). While significantly correlated with elbow extension (Spearman correlation: r=0.55, p=0.010, and r=0.55, p=0.010, respectively) and grip strength (Spearman correlation: r=0.45, p=0.035, and r=0.42, p=0.049, respectively), PCA-MD and DTW scores were not correlated with elbow flexion, shoulder abduction or finger extension ($p>0.05$).

Conclusion: This study establishes DTW as a methodologic alternative to PCA-MD for quantitatively evaluating motor control deficit. The strong correlation of both methods with functional outcomes not only reinforces their utility in understanding motor impairments, but also highlights that the temporal aspect of movement might not significantly influence these correlations during two-dimensional planar reaching. Additionally, certain components of the FMA-UE were not significantly correlated indicating that the planar reaching kinematics do not capture the full motor control deficit in stroke. Future studies will focus on extending methods to kinematics in three dimensions and to diverse