IS THE PROBLEM REALLY FOOT-DROP?

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INTRODUCTION

Impaired paretic swing limb advancement (SLA) is a hallmark of gait following stroke. The common school of thought posits ‘foot drop’ (impaired dorsiflexor function) as the primary cause of decreased paretic limb clearance during swing. SLA involves vertical shortening of the swing, relative to the stance, limb with simultaneous contributions from all three joints: hip, knee and ankle. Kinematic analyses illustrate reduced joint excursions throughout the paretic limb following stroke [1]. However, the influence of individual joint angular excursions during swing on toe clearance remains unknown. Sensitivity analysis enables determination of the influence of respective joint angles on toe clearance [2]. Here we investigated toe clearance sensitivity (TC_{sensitivity}) at: i) minimal toe clearance and ii) maximal limb shortening, during paretic limb swing, to the: hip, knee, and ankle joints. We hypothesized: 1) minimal toe clearance would be lower in participants post-stroke, but 2) toe clearance sensitivity to ankle dorsiflexion at either gait milestone would not differ between controls and participants post-stroke.

METHODS

We studied 16 participants (age: 57±14.37yrs; 13 male) with chronic (4.21±1.93yrs) post-stroke hemiparesis during overground walking at self-selected speed (SSWS) and 10 healthy controls who walked at matched speeds. Lower extremity kinematics were collected with 3D motion analysis. All participants post-stroke presented with lower extremity (LE) motor dysfunction (LE Fugl Meyer synergy: 15/22 ±2.78) and gait impairment (SSWS: 0.54m/s ±0.26).

Toe clearance sensitivity was defined as the partial derivative of toe clearance with respect to the paretic hip, knee, and ankle joints. We calculated TC_{sensitivity} to sagittal plane changes in the lower extremity joint angles throughout swing, thus a planar model was used (Fig. 1).

![Figure 1](attachment:figure1.png)

Student’s t-test was used to test for group differences in minimum toe clearance during swing. ANOVA was used to test for group x joint interactions for joint angle and TC_{sensitivity} at two points: 1) minimum toe clearance and 2) maximum paretic leg shortening, in swing. After correction for multiple tests, statistical significance was established at p<0.008.

RESULTS AND DISCUSSION

Surprisingly, participants post-stroke revealed greater minimal toe clearance in swing (p=0.001; Fig 2). Maximum hip flexion and ankle dorsiflexion during swing did not differ between groups (p>0.05). However, as expected, maximum knee flexion during swing was reduced post-stroke (p<0.0001).

Minimum toe clearance in swing
Minimum toe clearance (TC_{min}) during swing occurred at approximately 73% and 74% of the gait
cycle for controls and participants post-stroke, respectively. At TC_{min}, the joint angles of the hip and ankle did not differ between groups; however, the knee angle was reduced in participants post-stroke (26±15 degrees), relative to controls (48±12 degrees; \( p<0.0001 \)). TC_{sensitivity} to ankle dorsiflexion at TC_{min} did not differ between groups (\( p>0.05; \) Fig.3)). Interestingly, the pattern of TC_{sensitivity} was reversed in the hip and knee between groups. TC_{sensitivity} to 1) hip flexion and 2) knee flexion was exaggerated and reduced, respectively post-stroke (\( p<0.0001 \)).

**CONCLUSIONS**

Given that minimal toe clearance during swing was higher post-stroke than controls, two conclusions can be made. First, limited toe clearance (i.e., dorsiflexion function) during SLA may not be as problematic as usually considered. Second, exaggerated toe clearance likely results from: 1) impaired inter-joint coordination at the stance-to-swing transition, or 2) a compensatory mechanism.

The lack of difference between groups in ankle angle and TC_{sensitivity} to ankle dorsiflexion at both TC_{min} and PL_{short} argue against dorsiflexor dysfunction as the primary impairment of SLA in persons post-stroke. Further, reversal of TC_{sensitivity}, to hip and knee flexion between groups, at both gait cycle milestones suggests impairment of the dynamic coordination between these joints. The reduced ankle angle at both points suggests the causal mechanism may be impairment of the dynamic contribution to knee flexion by the gastrocnemius muscle in preparation for swing.

**REFERENCES**


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