COMBINATION OF ANKLE MUSCLE FUNCTIONAL ELECTRICAL STIMULATION (FES) & FAST TREADMILL WALKING THERAPY EFFECT ON POST-STROKE MOTOR CONTROL

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Introduction

Nearly 800,000 people experience a stroke annually in the US alone [1]. Stroke survivors are left burdened by financial problems from expensive healthcare procedures and missed work, and these issues are only compounded by the sudden presence of motor task difficulties [2]. Of particular concern are the dynamic changes that occur to a stroke survivor's gait pattern. Walking is the primary locomotion strategy used by individuals to navigate their environments, and when this ability is compromised, so is the overall quality of life. Gait impairments reflect motor control changes, where unimpaired gait motions are produced by more complex control schemes than impaired ones [3-6]. Unlike common measures of performance following treatments, such as walking speed, step-length symmetry, paretic propulsion, etc., the Dynamic Motor Control (DMC) Index provides insight about the effect of the treatment at the neural level on motor control complexity, and it has successfully been used for analyzing gait in individuals with cerebral palsy [3, 8].

In this study, we sought to answer two questions: 1. *"How does FastFES treatment (combined Fast treadmill walking and Functional Electrical Stimulation) impact post-stroke motor control, as measured by the DMC Index?"* and 2. *"What are the distinguishing pre-treatment gait features between those that responded to treatment and those that did not?"*

Methods

Using OpenSim 3.3, we created forward dynamic simulations tracking gait data of 8 post-stroke individuals [7] with patient-specific musculoskeletal models having 23 degrees-of-freedom and 92 muscles. Computed Muscle Control determined muscle activations of paretic lower-limb muscles, which were then used as inputs to non-negative matrix factorization where only a single module (group of co-activated muscles) was considered [6]. The DMC index is based on the variance accounted for (VAF) by this muscle module in reproducing the original activation signal, where VAF is inversely related to motor control. A DMC index value of 100 is equal to that of an average unimpaired individual, and smaller DMC index values represent decreased motor control complexity typical of impaired individuals. Following FastFES treatment, individuals were grouped as a *responder* if their DMC index values increased after treatment, and a *non-responder* otherwise.

Distinguishing pre-treatment gait features between the two groups were identified with Statistical Parametric Mapping (SPM). SPM reduces focal bias common with traditional, 0D analyses of time-varying data by not requiring the selection of a single instance (toe off, peak knee flexion, etc.) [9, 10].

Results and Discussion

The FastFES treatment increased the DMC index in 5 of the 8 individuals (Fig. 1a, green). Interestingly, the 3 non-responders (Fig. 1a, red) had the highest pre-treatment DMC index values. These results suggest that the treatment *is* effective at increasing motor control, but *only if the individual's motor control is sufficiently impaired*. Individuals with moderate motor control impairment may not benefit from this treatment. Furthermore, we identified larger ($p < 0.001$) pre-treatment knee flexion during 20-40% of gait (Fig. 1b, blue) and smaller ($p < 0.001$) support moment (sum of the sagittal-plane moments of the hip, knee, and ankle) [11] between 30-40% of stance (Fig. 1c, blue).

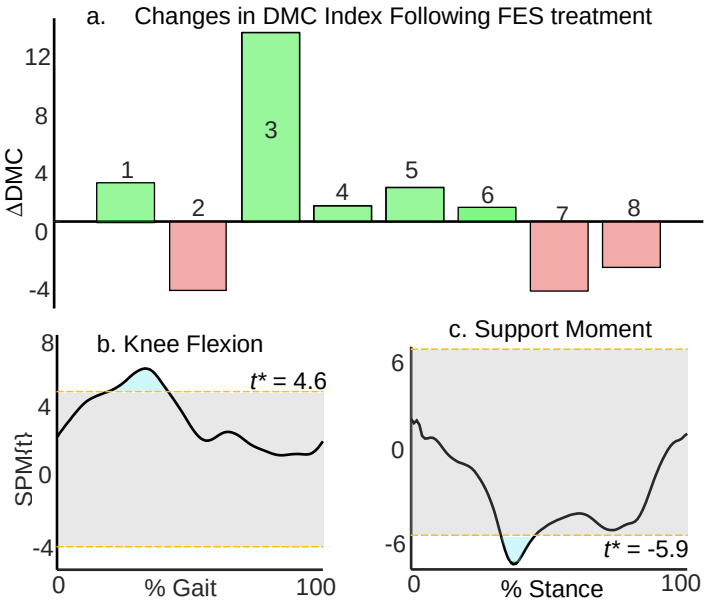

Figure 1: *Variation in treatment response and distinguishing pre-treatment gait features*. a. responders exhibit ΔDMC > 0 and non-responders ΔDMC < 0; b. Responders have larger knee flexion during 20-40% of gait; c. Responders have smaller support moments during 30-40% of stance.

Significance

While our findings are specific to one treatment for post-stroke gait, the approach may be extended to many other treatments for movement disorders. Quantifying treatment response in terms of motor control complexity provides useful information on whether the treatment is targeting the source of the impairment at the neural level. Identifying pre-treatment gait features that distinguish responders and non-responders not only allows for treatment outcome predictions, but clinicians can also learn about what areas to target for specific cases, leading to patient-specific treatment plans.

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