Statistical Analysis Plan

Protocol 5715: Effects of an Overground Propulsion Neuroprosthesis in Community-dwelling Individuals After Stroke

Clinical Trial Number: NCT06459401

1/3/2024

Objective

The primary objectives of this study were to i) determine the immediate and retained effects of overground walking with the propulsion FES neuroprosthesis and ii) evaluate the impact of neurostimulation timing on individual propulsion biomechanics.

Study Participants

Ten individuals in the chronic phase of stroke recovery (2 female; 53 ± 11 years old; 8 ± 1 years poststroke) completed this study. Each study participant completed one session that consisted of i) neurostimulation tuning and exposure, ii) overground gait training with propulsion FES, and iii) pre-session and post-session evaluations. Mean ± standard error (SE) are reported for all conditions and effect sizes (ES) are calculated using the pooled standard deviation (SD), unless otherwise specified. Medians are reported for all percent changes to account for outliers that may occur during the calculation of the percent change from baseline for those with small baseline values.

Inclusion criteria consisted of age at least 18 years, stroke chronicity greater than 6 months, ability to walk independently with or without an assistive device for at least 30 meters, and passive range of motion of the paretic ankle reaching neutral (90 degree angle). Participants were excluded if they had history of lower extremity joint replacement, metal implants beneath neurostimulation sites, and/or inability to communicate with the study team. All study procedures were approved by the Institutional Review Board at Boston University. Medical clearance was obtained for all study participants from their primary healthcare providers. All participants provided written informed consent.

Study Design

This study was designed to evaluate the immediate and carryover (i.e., post-session retention) benefits of walking with the propulsion FES neuroprosthesis. Before and after the session, unassisted comfortable and fast walking speeds were assessed using the 10-meter Walk Test (10mWT). Kinetic data were collected at 2000 Hz from six floor-embedded force platforms (Bertec Corp., Columbus, Ohio). Kinematic data were collected at 200 Hz using 18 optical motion capture cameras (Oqus, Qualisys AB, Göteborg, Sweden). Prior to data collection, the propulsion FES neuroprosthesis was tuned for each participant. Participants then completed two 5-minute treadmill walks at a comfortable speed to become accustomed with each of the two plantarflexor neurostimulation onset timing profiles and the transitions between walking with and without FES assistance. Participants then completed five sets of overground walks with the neuroprosthesis,

each set consisting of eight walks across a ten-meter walkway. These sets alternated between unassisted (sets 1, 3, 5) and assisted (sets 2 and 4) walking, with each assisted set assessing one of the two plantarflexor neurostimulation onset timings in a randomized order. Rest breaks were provided as needed after each walking trial, and participants wore a fall-prevention harness without bodyweight support for safety during all walks.

Data Processing and Analysis

Pre-session and post-session walking speeds were calculated as the average of three 10mWT trials. Peak propulsion was calculated as the maximum anteriorly directed ground reaction force normalized by bodyweight. Propulsion symmetry was calculated as the percentage of paretic propulsion impulse (i.e., the positive integral of the anterior ground reaction force) to the sum of the propulsion impulses of both limbs. All study data were processed using commercial motion analysis software (Visual 3D, C-Motion Inc., Boyds, MD) and a computing platform (MATLAB, The MathWorks Inc., Natick, MA). Kinetic and kinematic data were filtered using a fourth-order Butterworth lowpass filter with a cutoff frequency at 10 Hz. Timeseries data were stride-segmented by initial foot contact and normalized to a percentage of the gait cycle. Point metrics from the timeseries data were calculated in MATLAB by averaging all strides within each condition.

Commercial statistical software (SPSS Version 28, IBM Corp.) was used to conduct all statistical analyses with alpha set to 0.05. Normality of each variable's distribution was assessed using the Kolmogorov-Smirnov test. Depending on the normality of each variable, either paired t-tests or Wilcoxon signed-rank tests were used to determine i) immediate changes (i.e., from unassisted walking to propulsion FES-assisted walking), ii) differences in immediate changes between timing profiles (i.e., non-preferred timing vs. preferred timing), iii) retained changes in unassisted walking (i.e., from pre-session post-session). Descriptive statistics are reported as mean ± standard deviation (SD). Results are reported as mean ± standard error (SE), unless indicated otherwise. Percent changes (%Δ) are reported as medians. P-values (p) and standardized effect sizes (ES) are reported for each analysis.