Effect of wearable robotic leg orthosis on the weight bearing symmetry during sit-to-stand in individuals Post-stroke

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Abstract— **Sit-to-stand (STS) is an important component of independent mobility and is impaired in individuals post-stroke. We studied the effects of a wearable, robotic exoskeleton on hemiparetic limb asymmetry during STS. The device appears to facilitate weight bearing through the affected leg by providing assistance during the countermovement and rebound phases of STS.**

I. INTRODUCTION

Up to 40 to 50% of individuals who survive stroke experience physical disability. The ability to stand up from sitting is an important functional activity, a prerequisite for upright mobility and an important factor for independent mobility. However, sit-to-stand (STS) is biomechanically demanding and requires higher lower extremity joint torques than walking or stair climbing [1].

Recently, robotic devices have been used in neurorehabilitation to facilitate treatment efficacy. The Tibion Bionic leg is a mobile, intention-based robotic device designed to allow individuals post-stroke to perform activities more normally [2]. Results to date have shown improvements in balance, gait and functional performance in individuals post-stroke following therapeutic intervention using the Tibion Bionic Leg (TBL) [3].

Here we studied the effects of actuated limb assistance on hemiparetic limb asymmetry during STS using unilateral and bilateral vertical ground reaction forces (vGRF). We hypothesized that the actuated limb assistance provided to the paretic side by the TBL would promote more symmetrical movement and force production by individuals post-stroke.

II. METHODS

A. Subjects

Seven individuals with hemiparesis (Age 57.57 ±19.48 yr, time since stroke 70.7 ±34.45 mnths, 1 female) resulting from at least one, but no more than three, unilateral strokes

resulting in either cortical or subcortical lesions (confirmed by CT or MRI), having at least minimal ability to ambulate independently on level ground (i.e., physiologic ambulator) with or without an assistive device participated. Five healthy participants (Age 46.4 ±19.62 yr, 3 female) with no neurologic or orthopaedic impairments affecting walking also participated.

B. Tibion Bionic Leg (TBL)

The Tibion Bionic Leg is a mobile, wearable, intention-based robotic limb orthosis (Tibion Pk-100 Bionic Leg, Tibion Corporation, Sunnyvale, CA) developed as a therapeutic device. The device is actuated to supply force to assist or resist leg extension and flexion providing limb assistance against gravity during extension (as in sit-to-stand or free standing) and controlled flexion (as in stand-to-sit).

Force sensors placed under the foot detect a threshold force and trigger the actuation. In its primary mode (AUTO) the device clearly activates to assist the motion of the wearer. Three settings can be adjusted to individualize participant assistance or therapeutic challenge: *threshold* (force criterion required to activate the device), *assistance* (amount of assistance provided as percentage of body weight) and *resistance* (resistance provided during controlled flexion as in stand-to-sit or stair descent) [2].

C. Outcome Measures

The MiniBEST was performed both with and without the TBL to determine global effects on balance using readily available clinical markers of balance function [4]. 3D motion analysis data were collected while healthy and stroke participants performed 3 trials of STS in each of 4 different conditions: *No-TIB* (no TBL), *LOW* (Threshold=40, Assistance=30 & Resistance= low), *MED* (Threshold=30, Assistance=50 & Resistance= medium) *and HIGH* (Threshold=20, Assistance=70 & Resistance= high). Vertical ground reaction forces were corrected for the weight of the device. 6 key events of STS were identified from the total vGRF vector: *Initiation* (initial force change from sitting), *Counter* (lowest recorded vGRF following initiation), *Seat Off* (identified using seat switch), *Peak* (peak vGRF during STS), *Rebound* (lowest force value following peak force), and *Standing* (steady standing identified by leveling of the force curve to normal postural sway)[5]. The mean vGRF produced by each leg was calculated over each of 5 phases marked by the 6 STS events; *phase I* (initiation-counter), *phase II* (counter-seat

off), *phase III* (seat off-peak), *phase IV* (peak-rebound) and *phase V* (rebound-standing). The TBL was placed on the affected leg of stroke participant and a randomly chosen leg in healthy participants.

D. Data Analysis

Weight bearing symmetry was studied by calculating the differences, as percentage of body weight, in the vGRF between the Tibion/Paretic and No Tibion/ non-paretic leg (NoTibion/NP-Tibion/P). Due to the small sample size available for this preliminary analysis, we present descriptive statistics and 95% confidence intervals for each parameter.

III. RESULTS

In the No-TIB condition healthy controls revealed minimal to no difference between legs. In contrast, there was a notable asymmetry in stroke participants usually favoring the non-paretic (NP) leg. However, during the phase II of STS (*counter – seat off*) stroke participants favored their paretic (P) leg.

In healthy controls, the TBL induced asymmetries in with clear trends revealing greater vGRF produced by the non-TBL leg in phases I and II as the level of assistance was increased. No differences were revealed between limbs in phase III. In Phase IV (*peak-rebound*) the TBL produced asymmetry favoring the no TBL leg while in Phase V (*rebound – standing*) asymmetry favored the leg wearing the TBL. Of note, asymmetries were observed only for the HIGH assistance condition.

Stroke participants revealed a trend favoring the Paretic limb in Phase I with the greatest symmetry between the paretic (P) and NP legs for the MED condition. In phase II there was an increase towards weight bearing by the NP leg in the MED condition. In phase IV there was a systematic trend towards greater vGRF produced by the NP leg leading to increased asymmetry between the legs. In Phase V a weight bearing symmetry was improved in all TBL conditions and revealed improvement in P leg vGRF.

MiniBEST test scores were improved in the TBL vs. No-Tib condition (mean increase of 2.143, 95% CI 0.4185-3.867) indicating global improvements in balance and stability when wearing the device.

IV. DISCUSSION

In healthy individuals, the TBL induced some asymmetries – as should be expected as an effect of the device itself. In stroke participants, the TBL improved weight bearing symmetry in phases I and V of STS (Figure 1). In phase I, paretic limb weight bearing improved gradually with increasing assistance. Moreover, we found that the individuals with stroke increased weight bearing during phase V (peak-standing). The TBL appears to provide them with adequate assistance in extension and in full standing, hence improving weight bearing through the affected side.
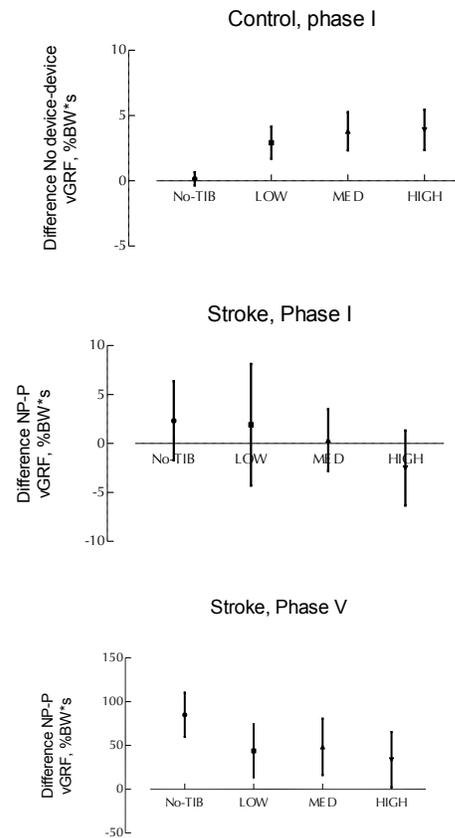

Fig. 1. Mean ± 95% confidence interval for the differences between the no TBL/NP limb and the with TBL/P limb for controls in phase I and for stroke participants in Phases I and V for vGRF as percentage body weight.

V. CONCLUSION

These preliminary results suggest the actuated TBL allows the user to involve their weaker leg more than would otherwise be possible, enabling greater weight bearing through the involved lower extremity. When used during therapy, the TBL may enhance the capability of the wearer to perform activities with more appropriate biomechanics. Repetition of appropriate movement patterns with greater engagement of the paretic limb may ensure functional improvements.

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