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.

1 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 [2, 3]. The Tibion Bionic Leg (TBL) is a wearable, intention-based robotic device designed to allow individuals post-stroke to perform activities more normally [4]. Results to date have shown improvements in balance, gait and functional performance in individuals post-stroke following therapeutic intervention using the TBL [3].

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

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2 Methods

2.1 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 producing 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.

2.2 Tibion Bionic Leg (TBL)

The Tibion Bionic Leg is a mobile, wearable, intention-based robotic limb orthosis (Tibion 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) [4].

2.3 Outcome Measures

The MiniBEST was performed both with and without the TBL to assess global effects on balance using readily available clinical markers of balance function [5]. 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) [6]. The mean vGRF produced by each leg was calculated over the 5 phases defined by these 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 applied to the affected leg of stroke participants and a randomly chosen leg in healthy participants.

2.4 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.

3 Results

In the **No-TIB** condition healthy controls revealed minimal to no difference between legs while stroke participants revealed a notable asymmetry, typically favoring the non-paretic (NP) leg except during Phase II of STS (*counter – seat off*) where they favored their paretic (P) leg with the mean vGRF difference of 2.32, -3.55, 16.13, 11.04 and 85.04 for Phase I, II, III, IV and V respectively.

In healthy controls, the TBL induced asymmetries. Clear trends revealed 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, most prominent asymmetries were observed for the HIGH assistance condition.

Stroke participants when wearing the TBL revealed a trend favoring the P limb. In Phase I the greatest symmetry between the P and NP legs was observed in the MED assistance condition. However, no differences were revealed between limbs in phase II and phase III. A systematic trend towards greater vGRF produced by the NP leg leading to increased asymmetry between the limbs was observed in phase IV. In Phase V weight bearing symmetry was improved in all TBL conditions and revealed increased P leg vGRF.

The 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 TBL.

4 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, P 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 assistance in extension and in full standing, hence improving weight bearing through the more affected side.

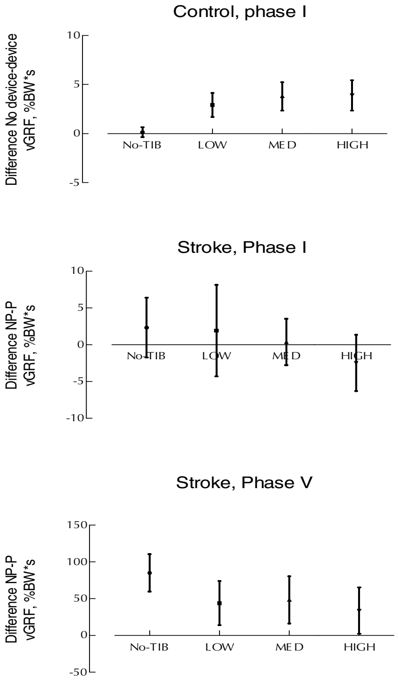

Fig. 1 Mean ± 95% confidence interval for the differences between the no TBL/NP limb and the with TBL/P limb for controls in phase I and for stroke participants in Phases I and V for vGRF as percentage body weight

5 Conclusion

These preliminary results suggest the immediate effects of the actuated TBL allow the user to involve the 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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